**FIG. 2**

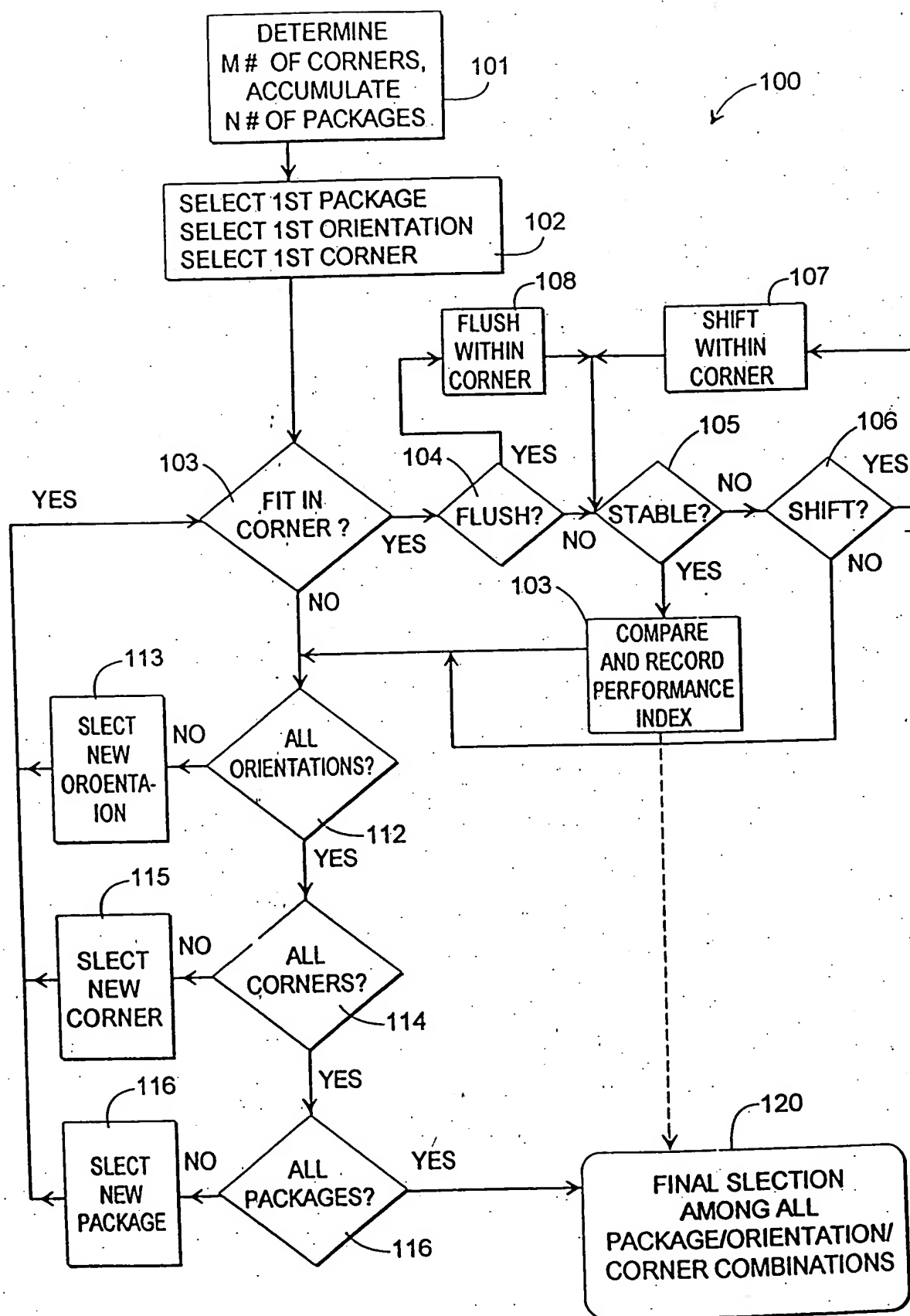


FIG. 3

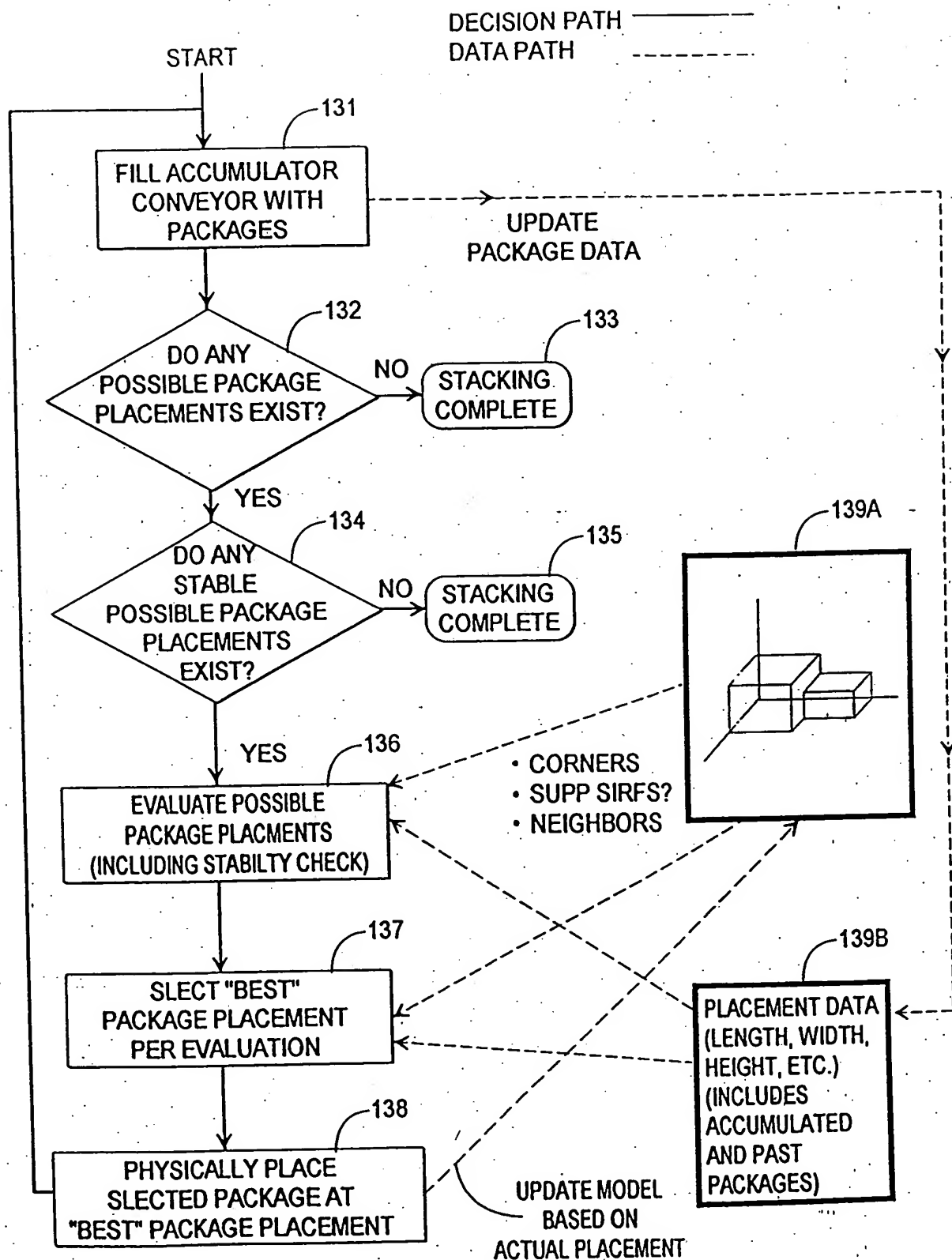
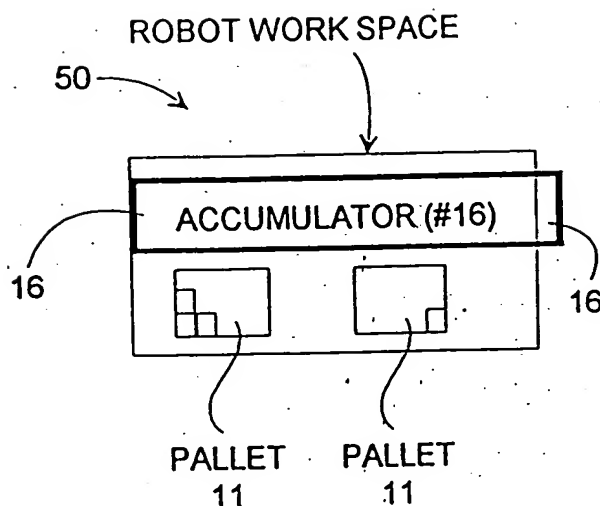
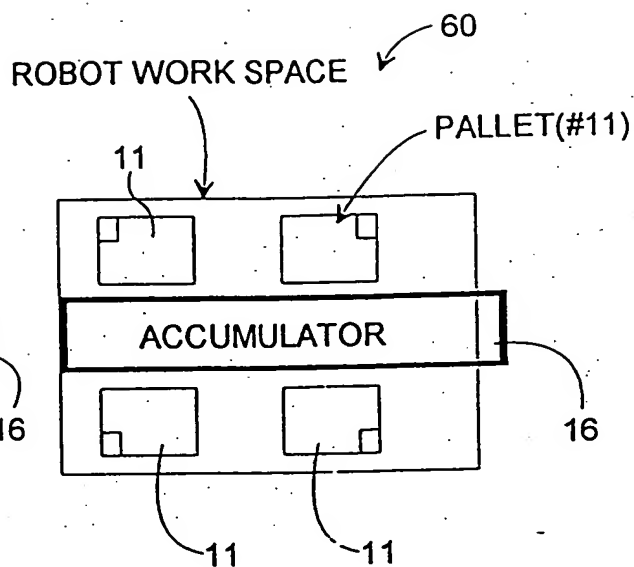
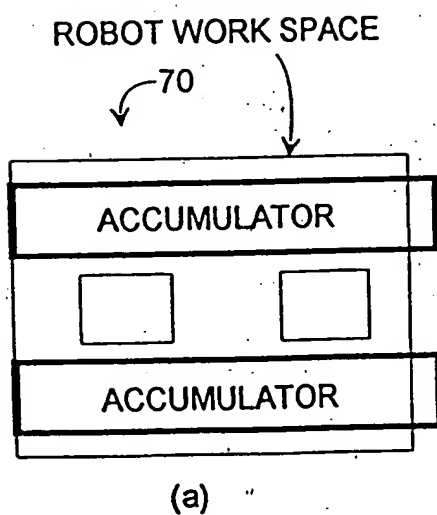
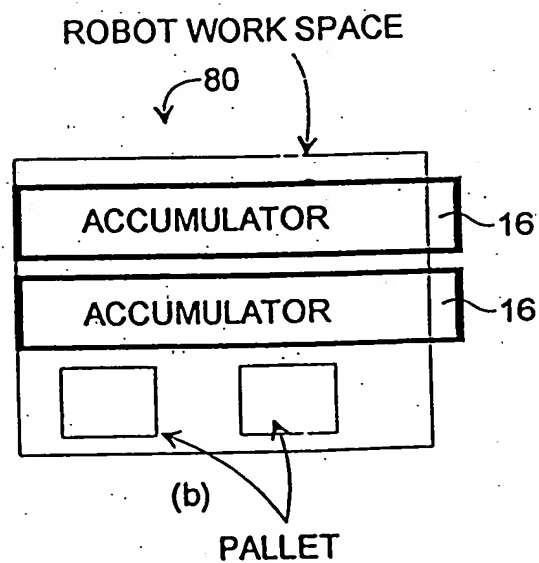
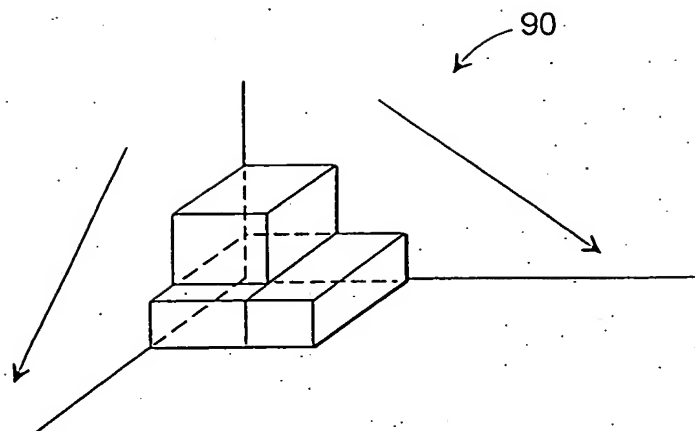
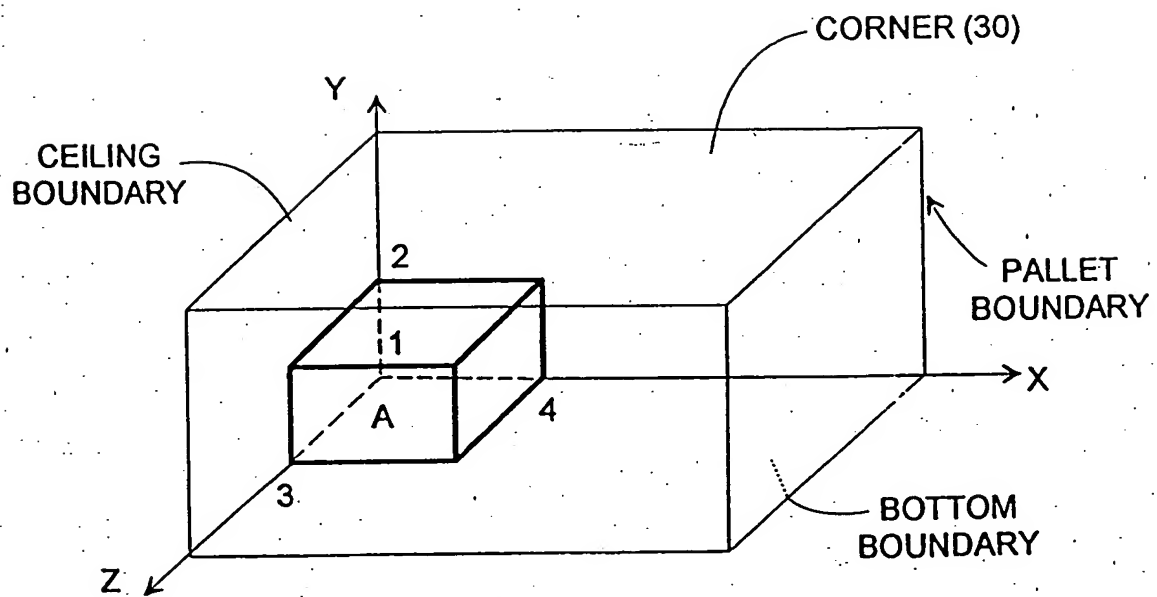
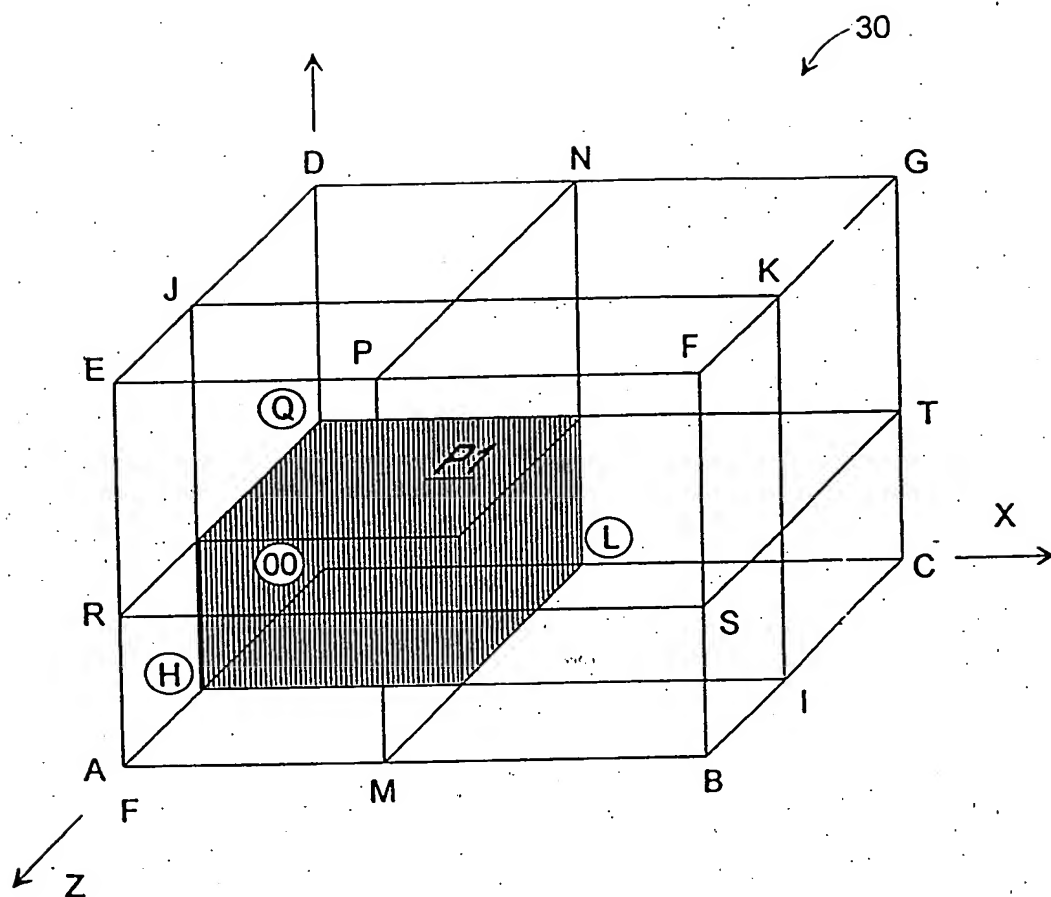


FIG. 4

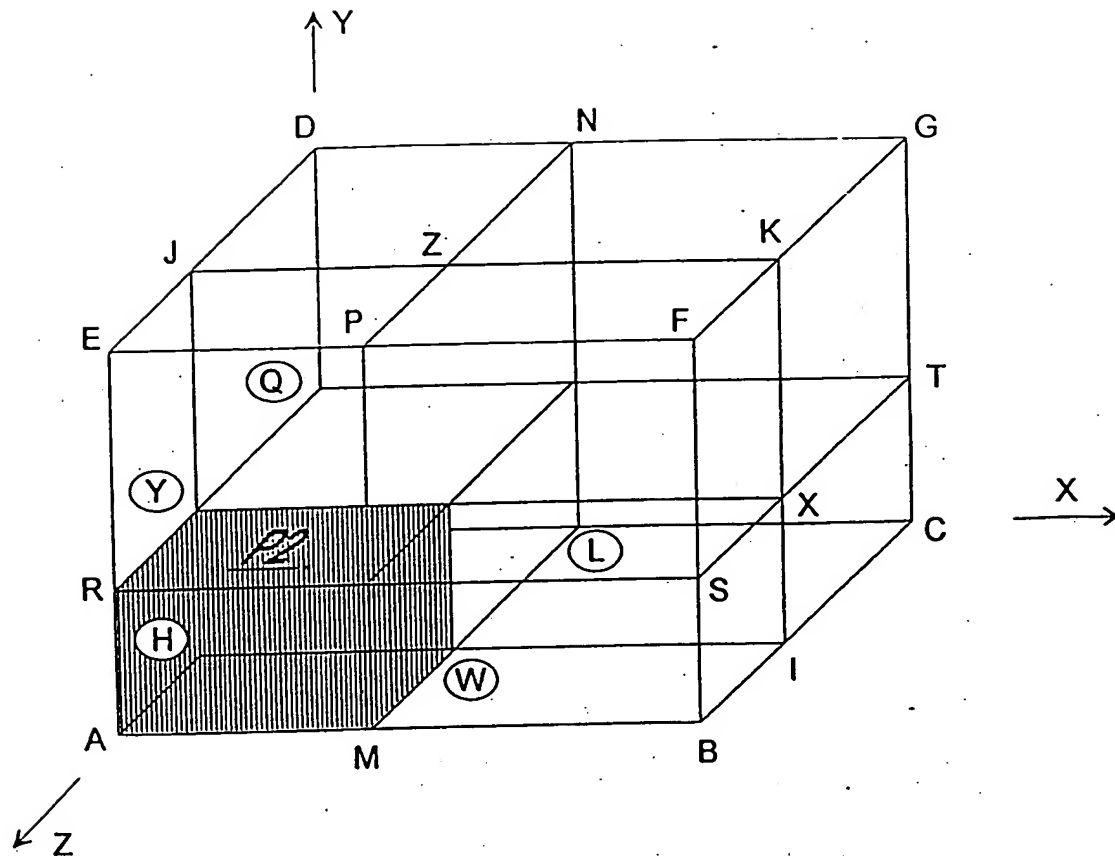
**FIG. 5****FIG. 6****FIG. 7****FIG. 8**

**FIG. 9****FIG. 10**



	CORNER #	ORIGIN	BOUNDED BY
BEFORE PLACEMENT	1	00	OABC DEFG
AFTER PLACEMENT	2	H	HABI JEFK
	3	L	LMBC NPFK
	4	Q	QRST DEFG

**FIG. 11**



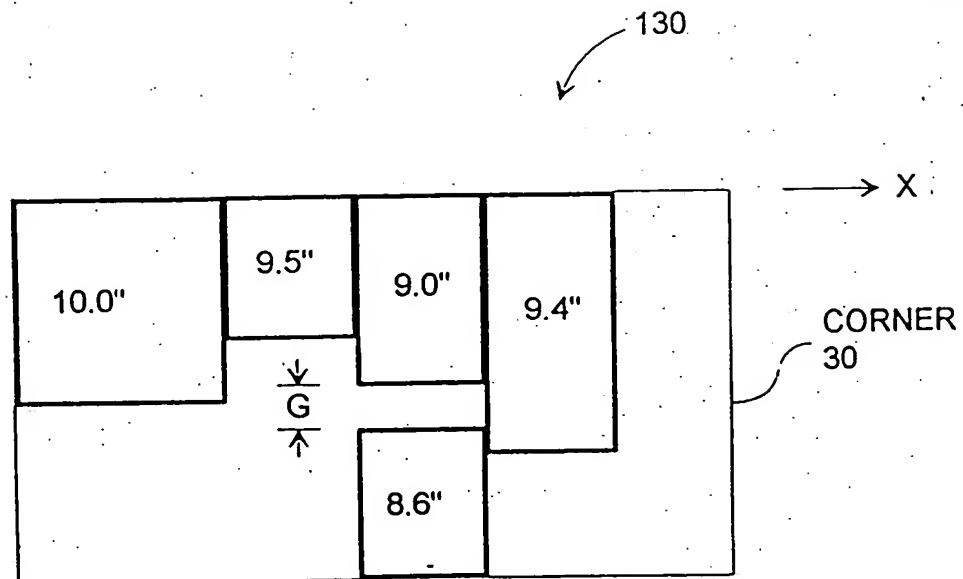
	CORNER #	ORIGIN	BOUNDED BY
BEFORE PLACEMENT	2	H	HABI JEFK
	3	L	LMBC NPFG
	4	Q	QRST DEFG
AFTER PLACEMENT IN CORNER 2	3	L	LMBC NPFG
	4	Q	QRST DEFG
	5	W	WMIB PFKZ
	6	Y	YRSX JEFK
AFTER MERGING	3	L	LMBC NPFG
	4	Q	QRST DEFG

(CORNER 5 MERGED INTO CORNER 3)

(CORNER 6 MERGED INTO CORNER 4)

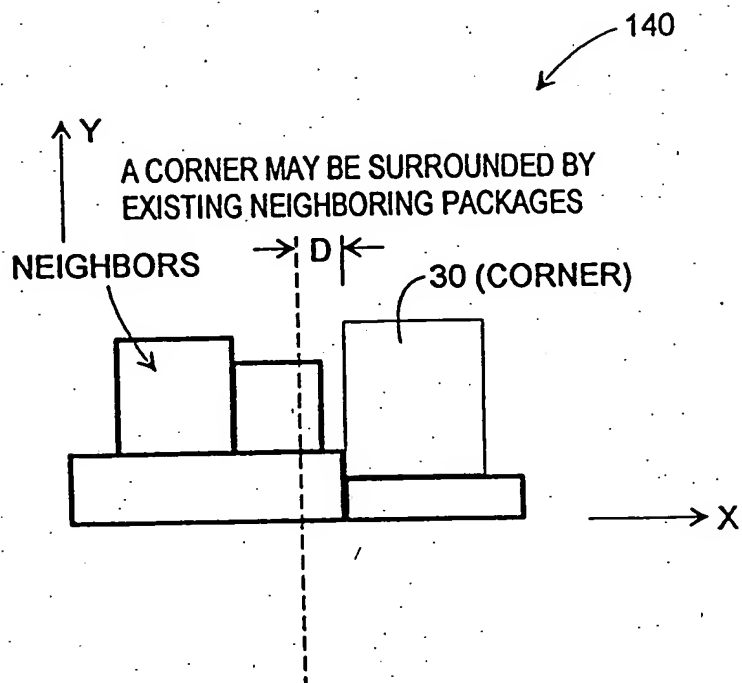
**FIG. 12**



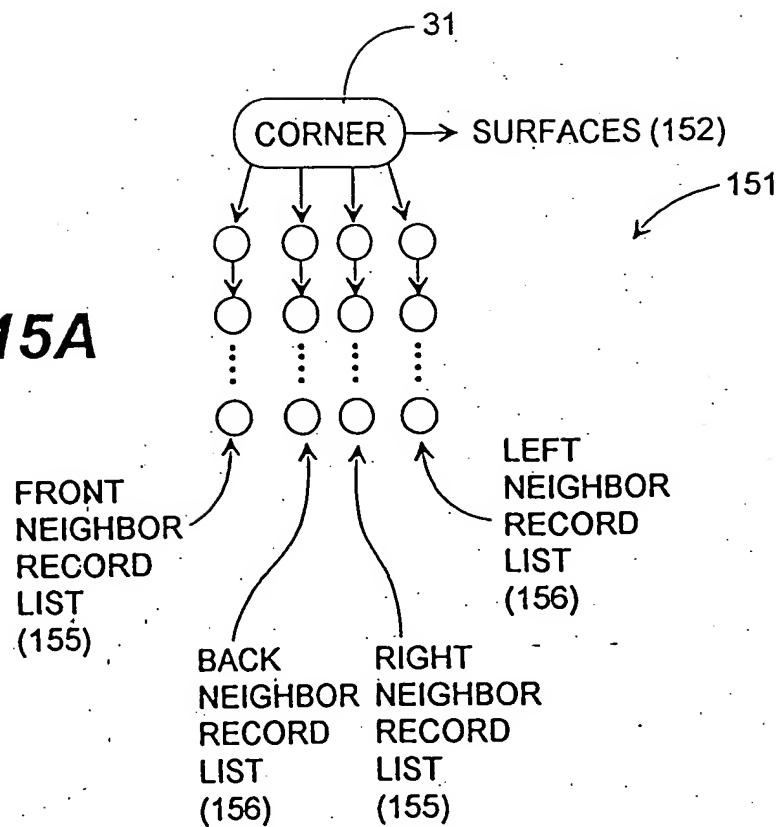
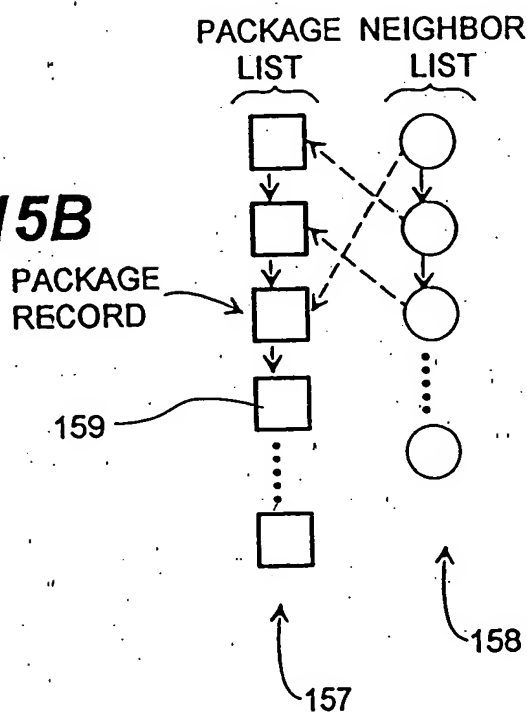


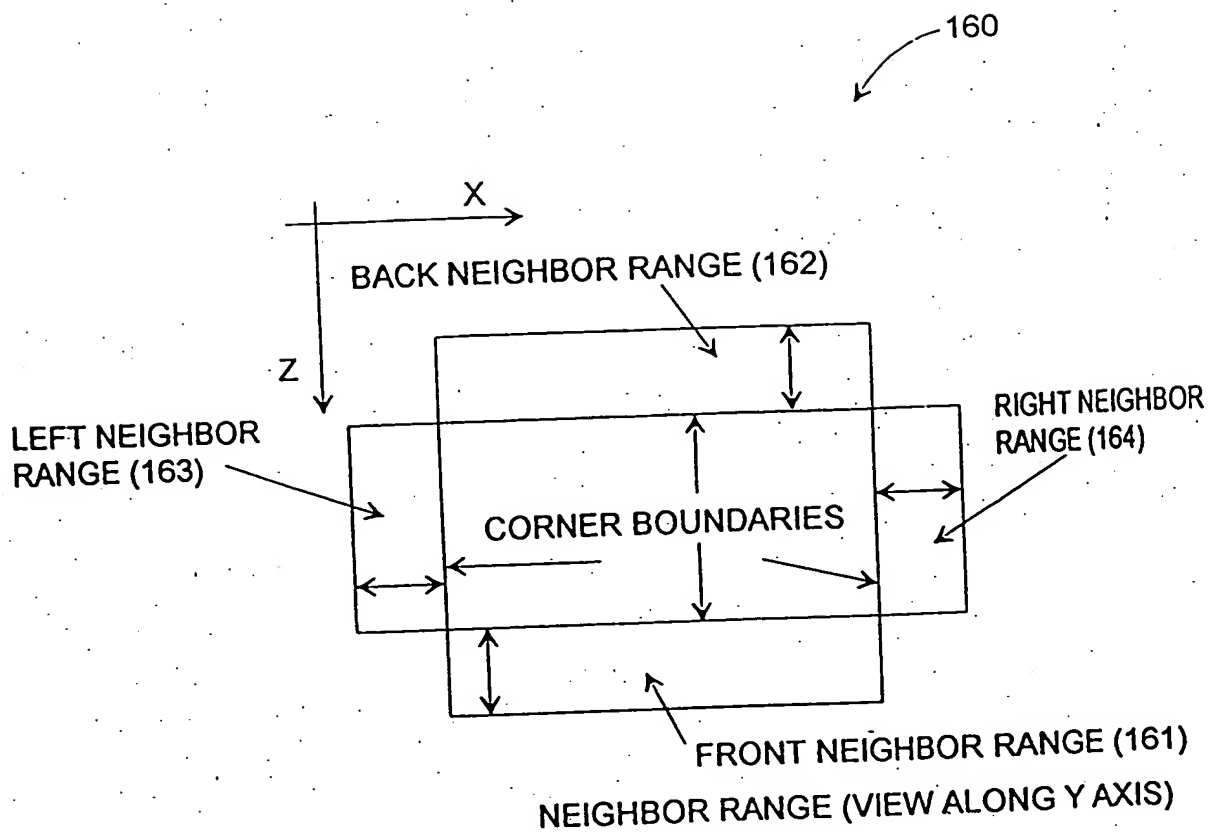
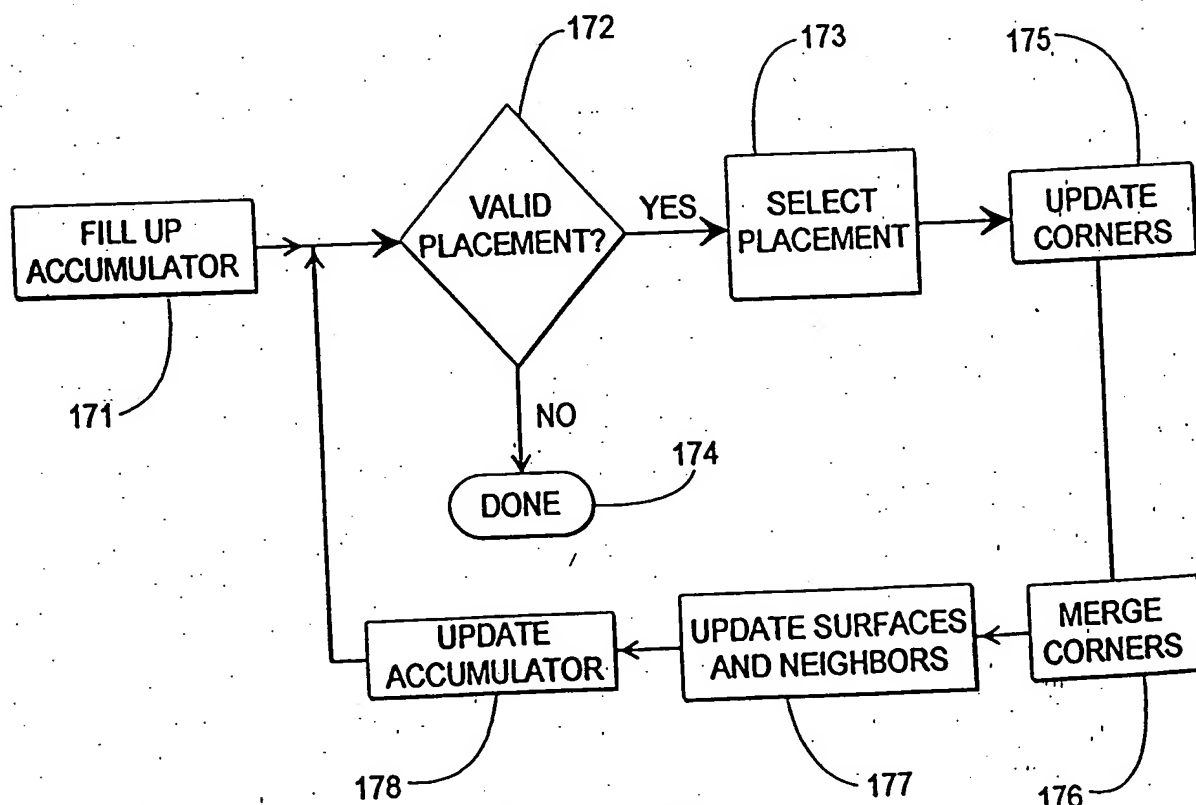
CORNER SURFACES WITH HEIGHT (Y DIMENSION) LABELED

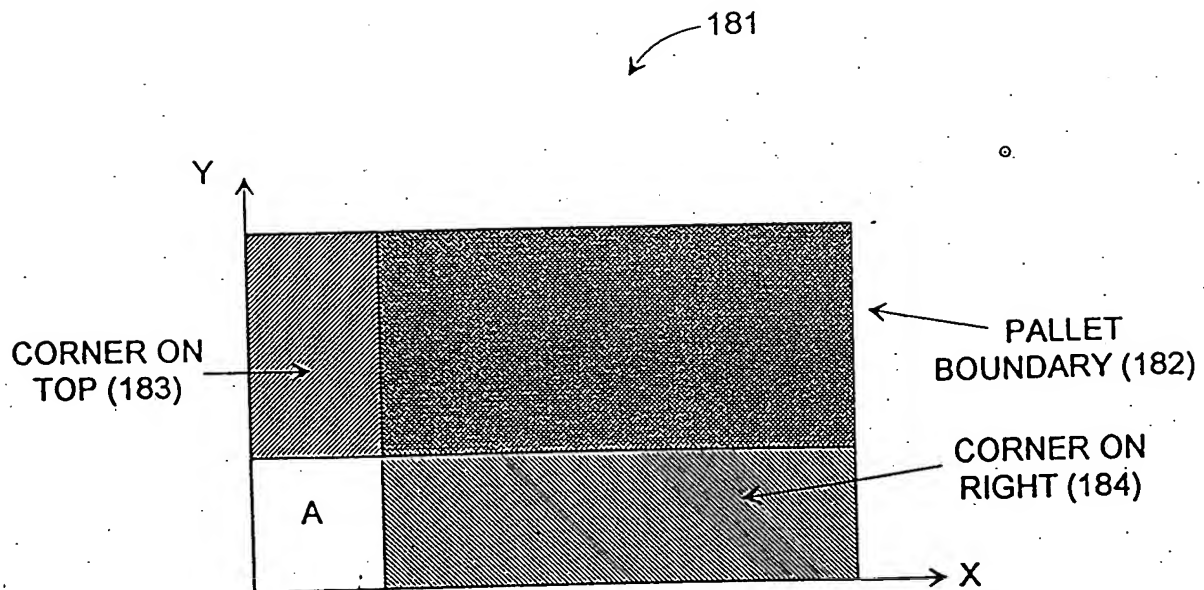
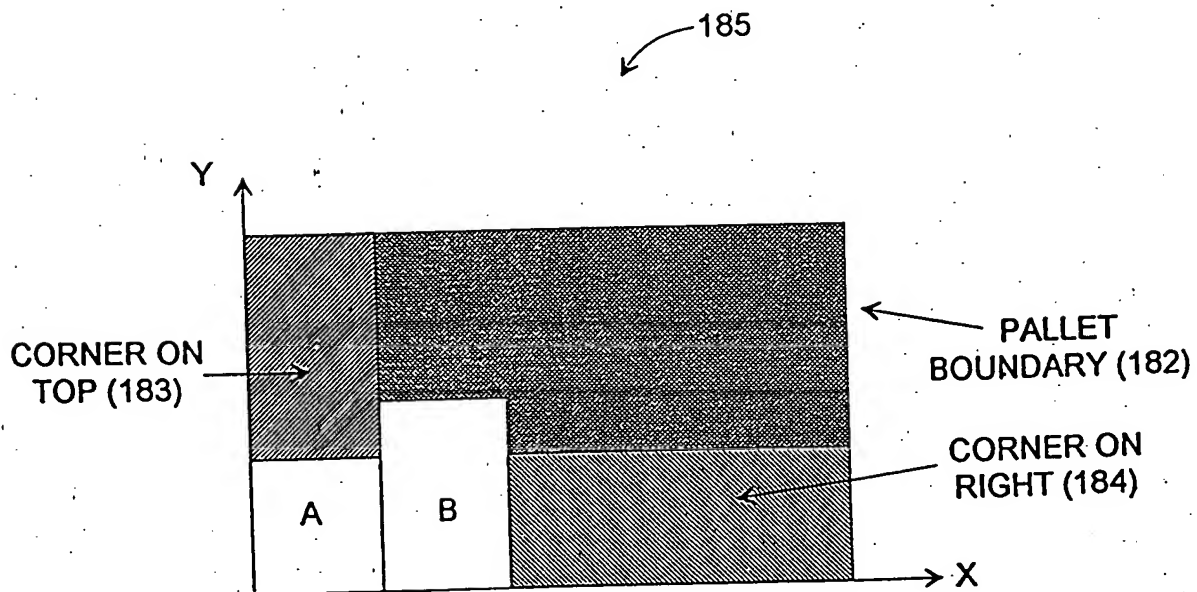
**FIG. 13**

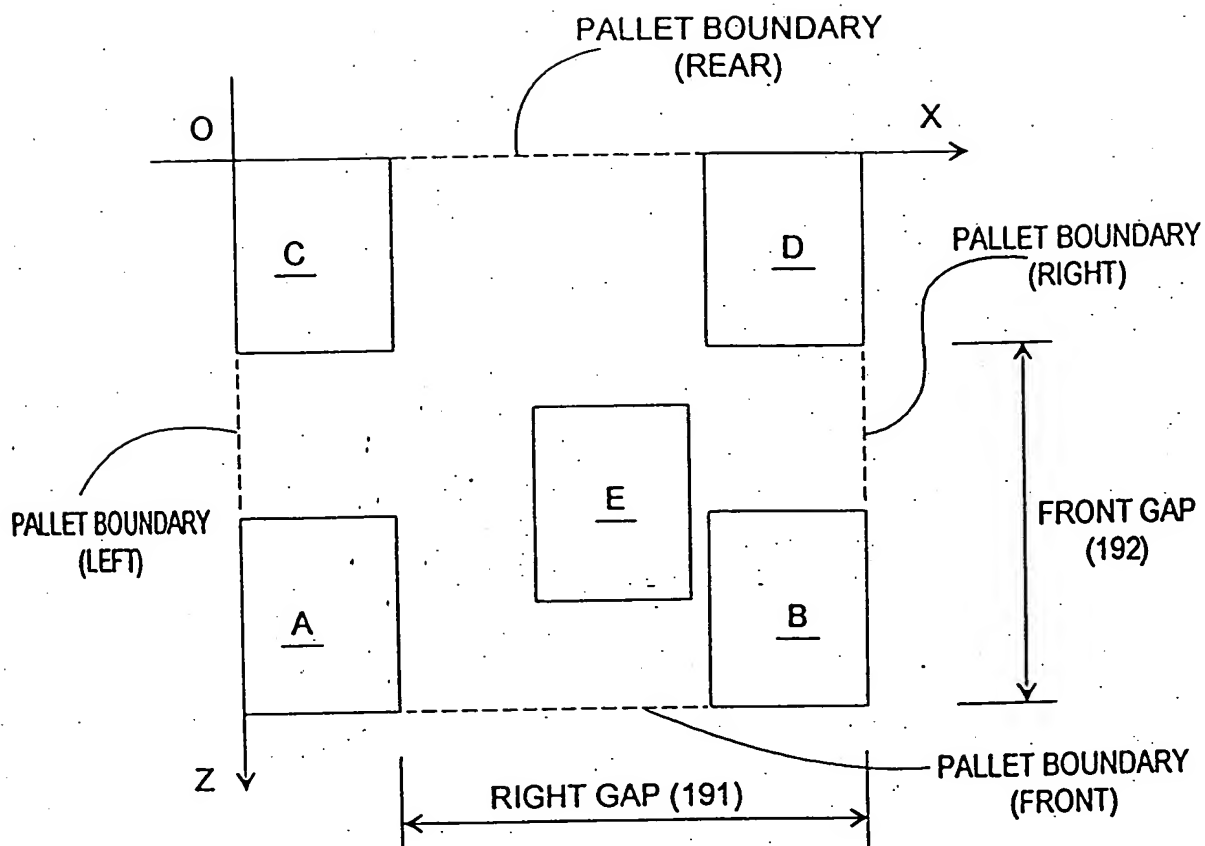


**FIG. 14**

**FIG. 15A****FIG. 15B**

**FIG. 16****FIG. 17**

**FIG. 18A****FIG. 18B**



POSITION A - FRONT FLUSHING  
 POSITION B - FRONT AND LEFT FLUSHING  
 POSITION C - NO FLUSH  
 POSITION D - RIGHT FLUSH  
 POSITION E - SHIFTED

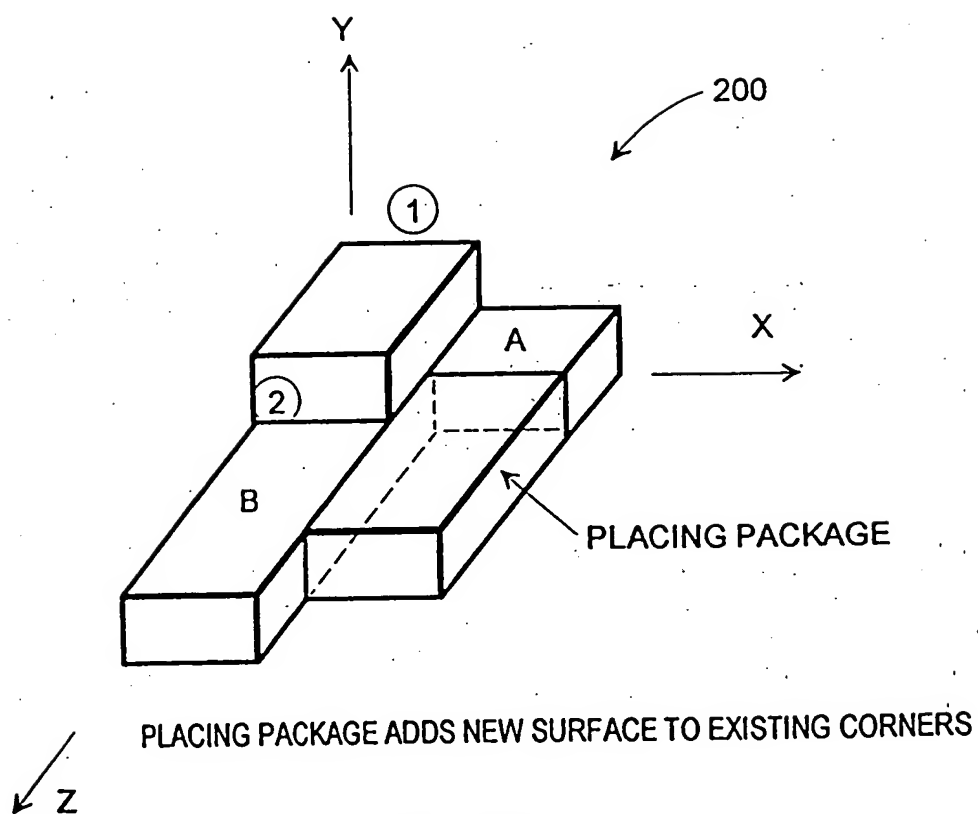
PACKAGES C AND D BOTH HAVE FRONT GAP BETWEEN THEMSELVES AND FRONT PALLET BOUNDARY

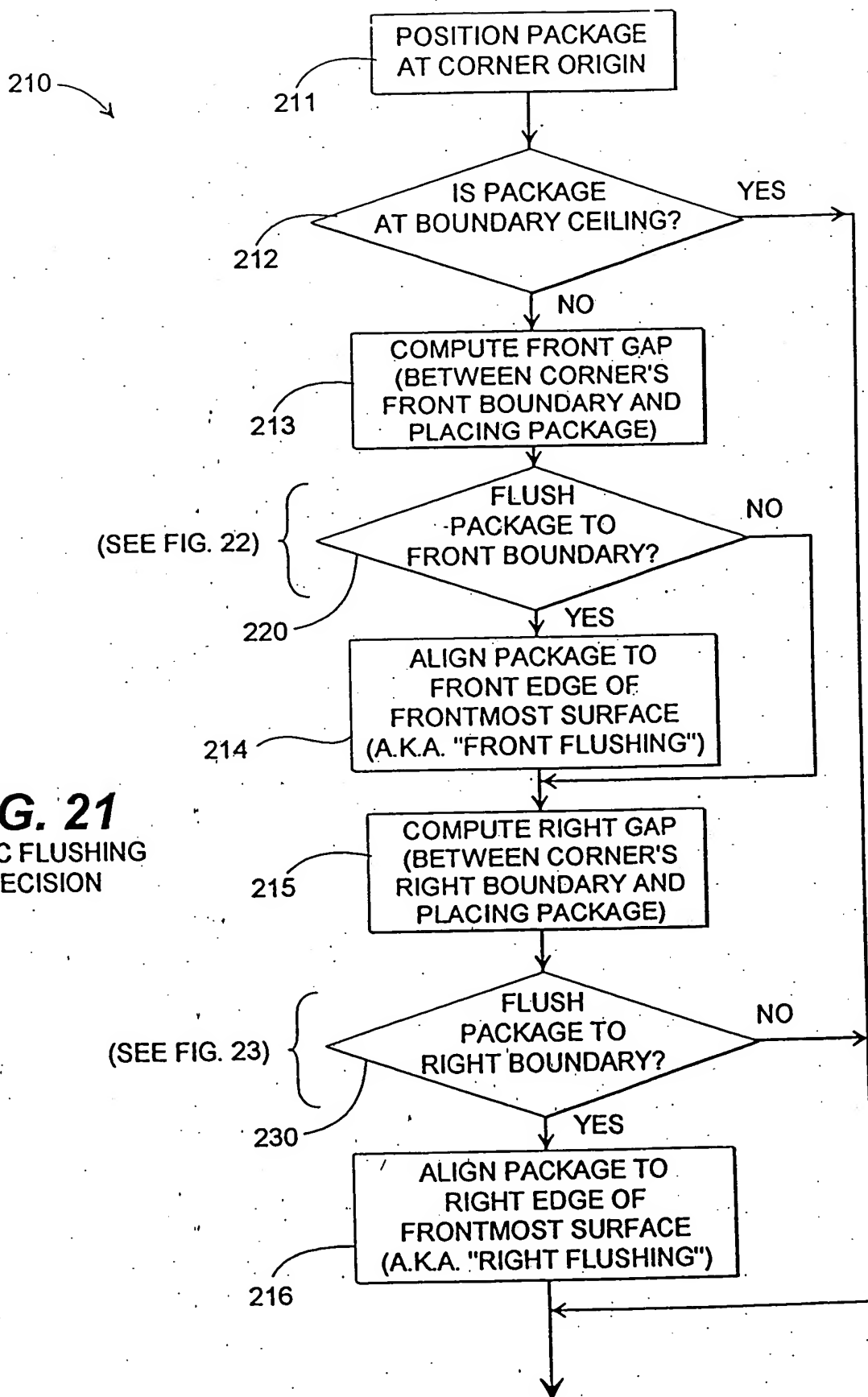
PACKAGES A AND B HAVE NO FRONT GAP

PACKAGES A AND C BOTH HAVE SAME RIGHT GAP BETWEEN THEMSELVES AND RIGHT PALLET BOUNDARY

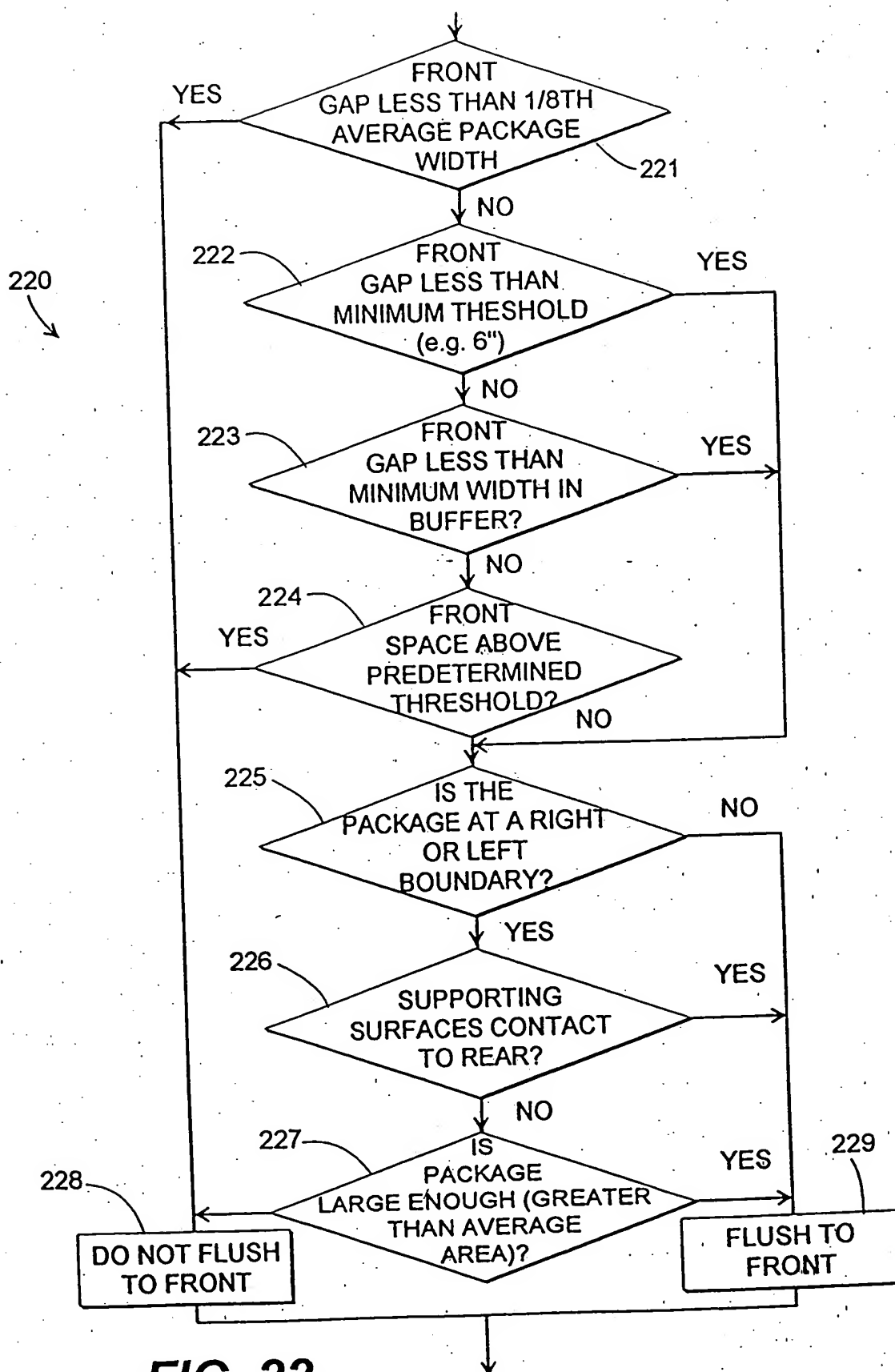
PACKAGES B AND D HAVE NO FRONT GAP

**FIG. 19**

**FIG. 20**

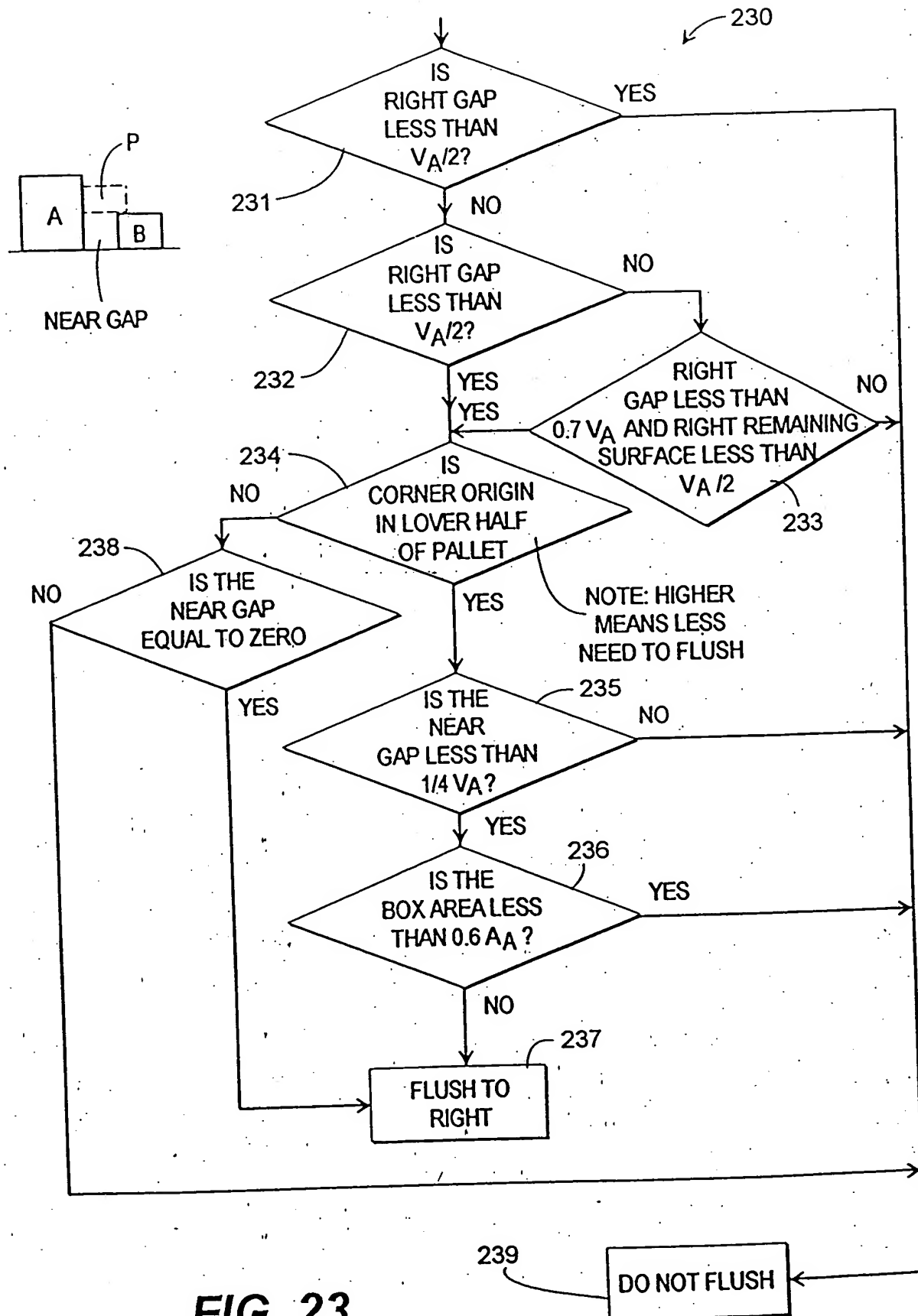


**FIG. 21**  
BASIC FLUSHING  
DECISION



**FIG. 22**  
FRONT FLUSHING  
DECISION





**FIG. 23**  
(RIGHT FLUSHING DECISION)

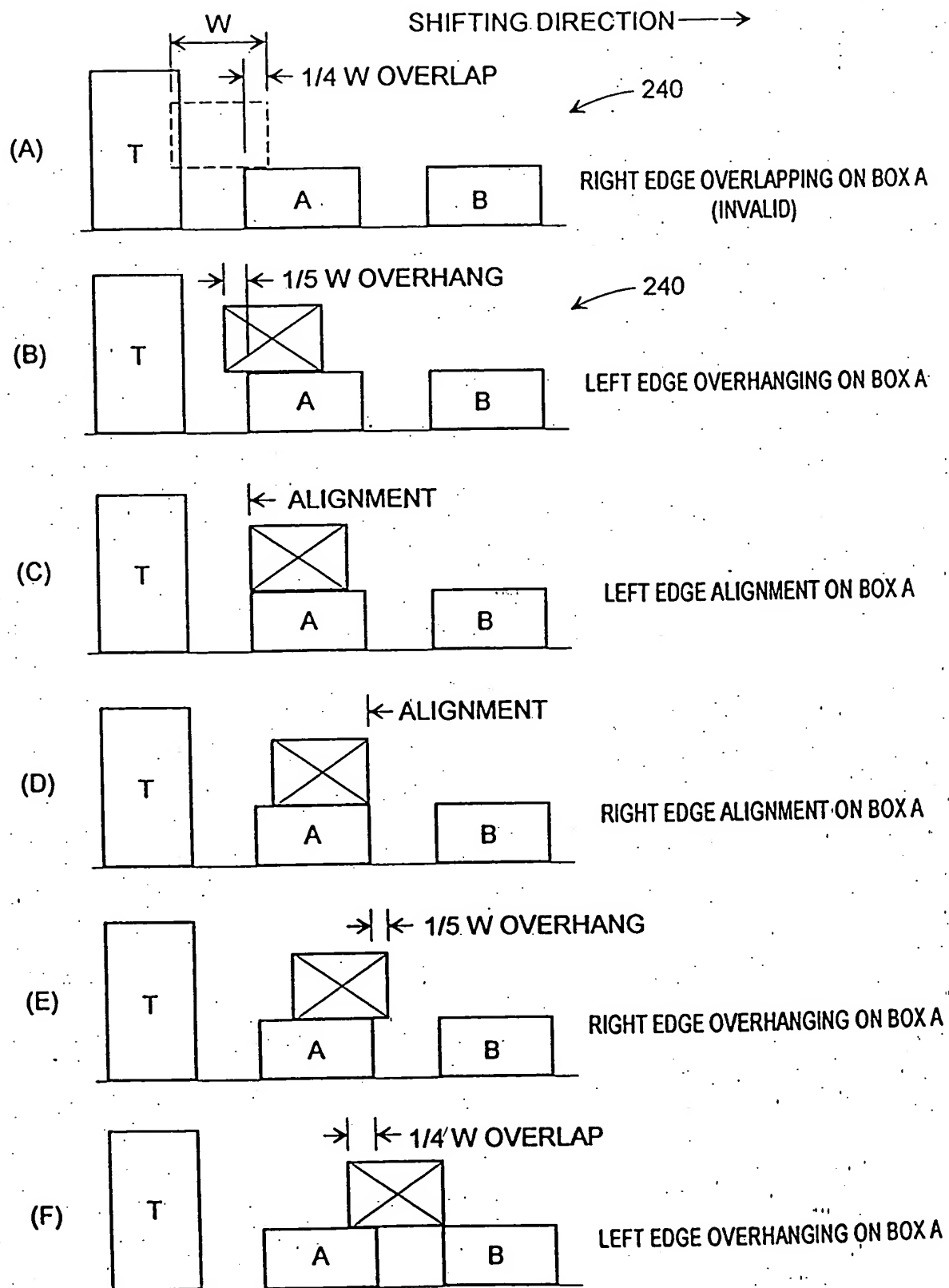
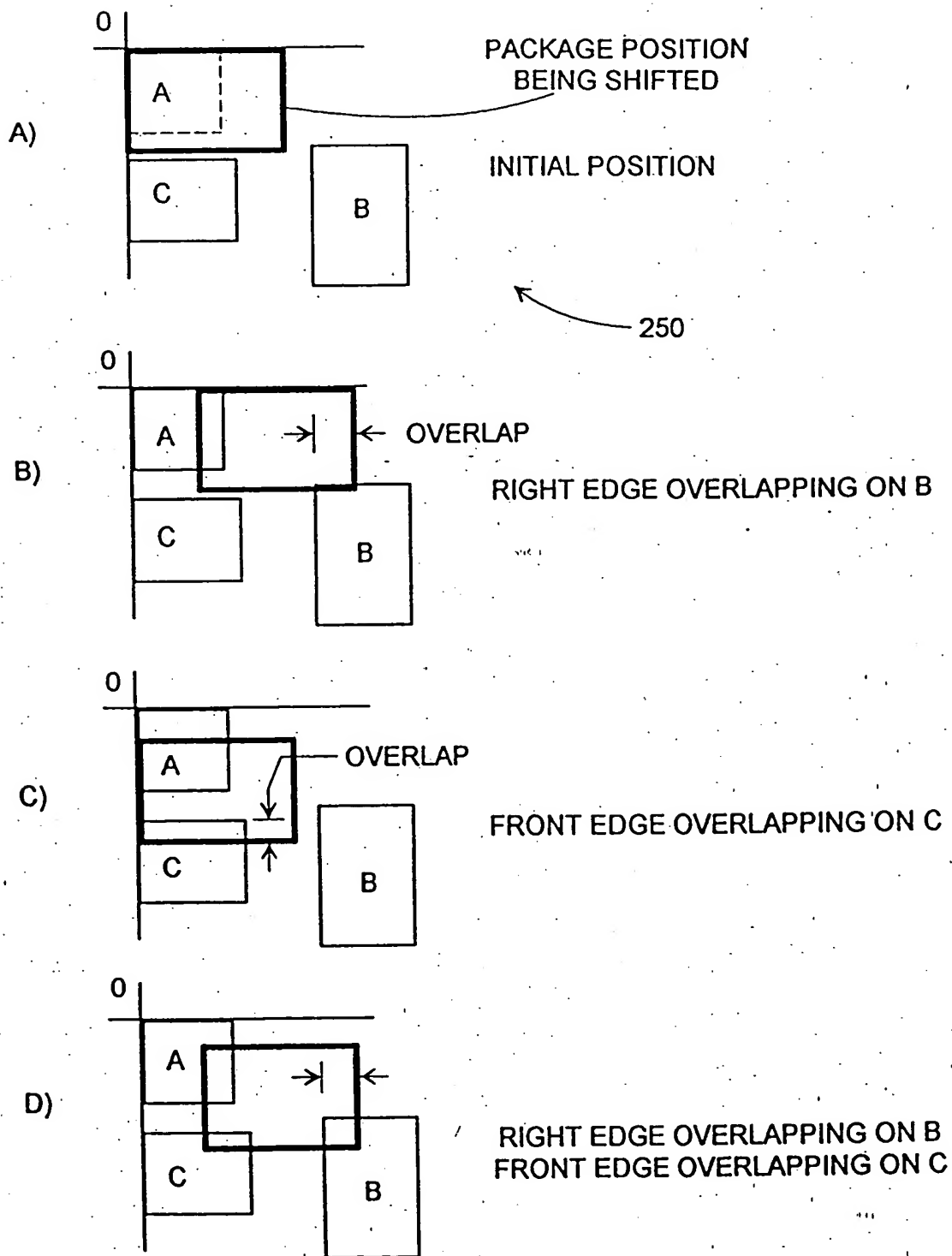
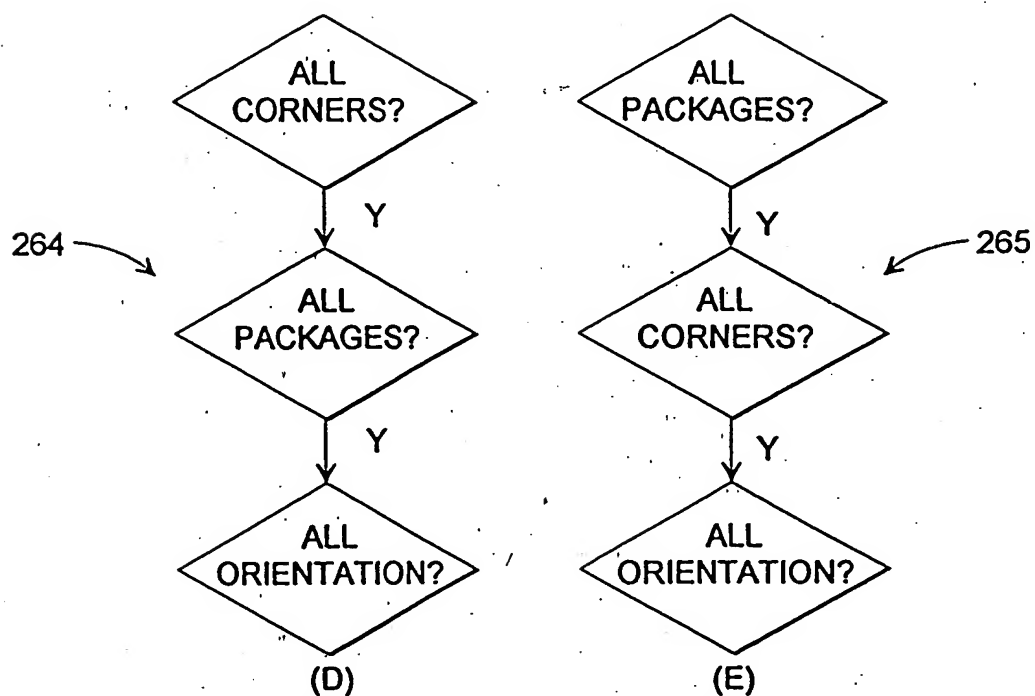
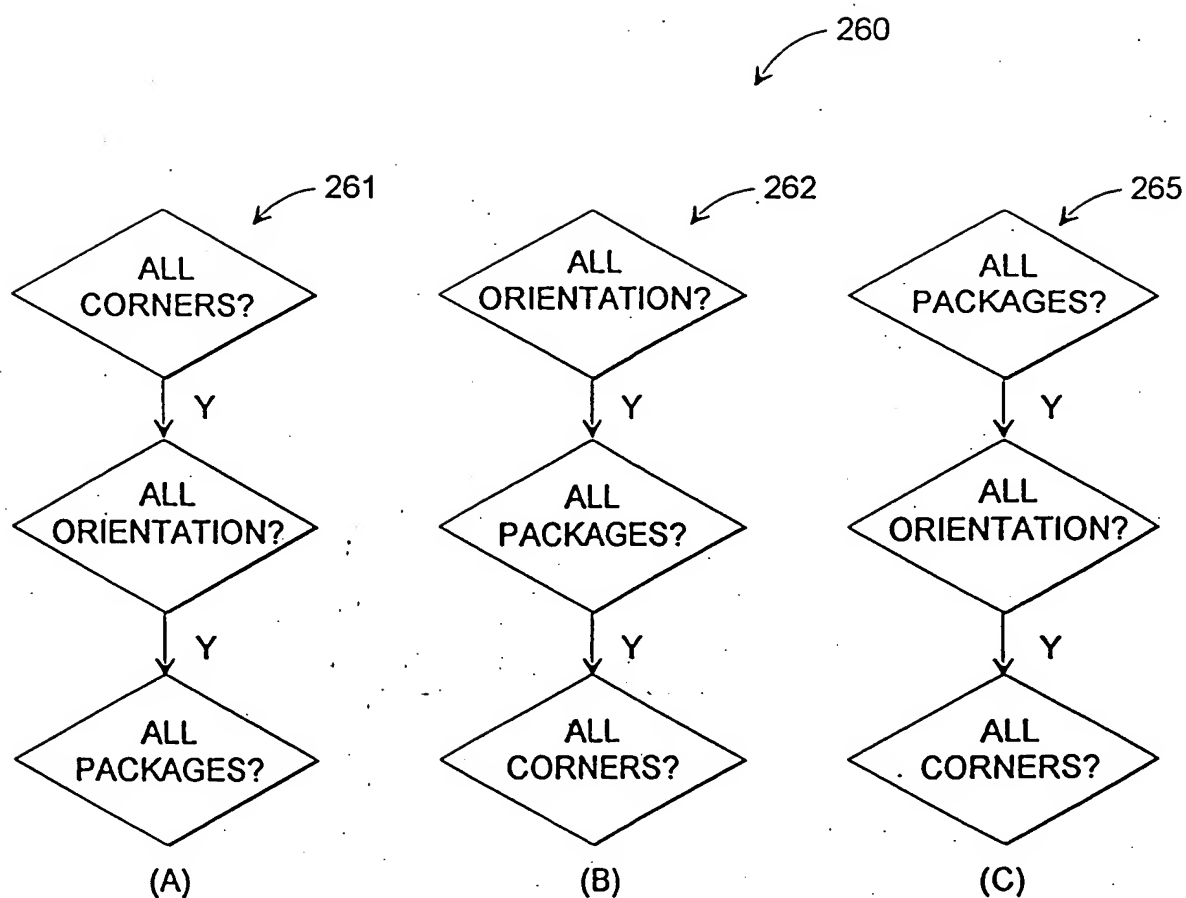


FIG. 24

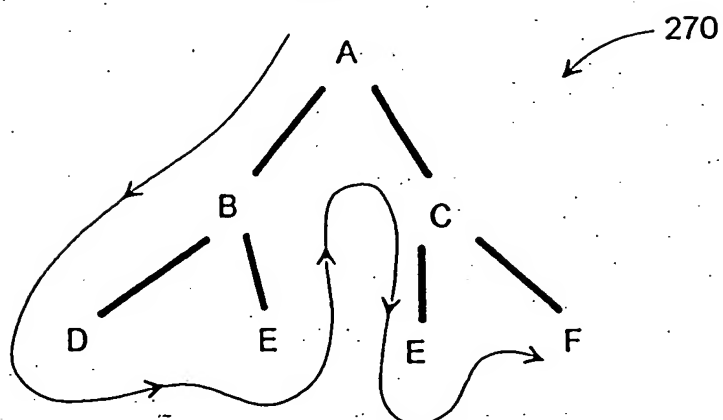
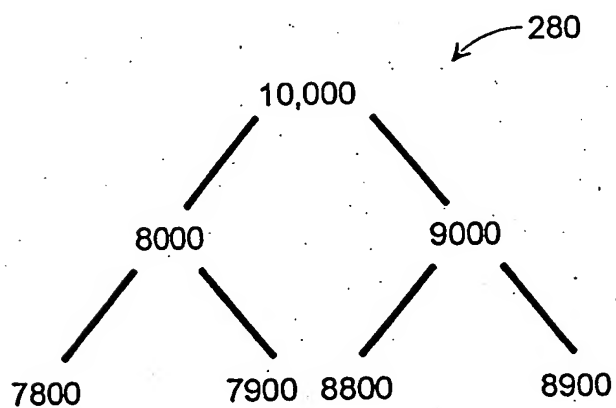
## (TWO DIMENSIONAL SHIFTING)

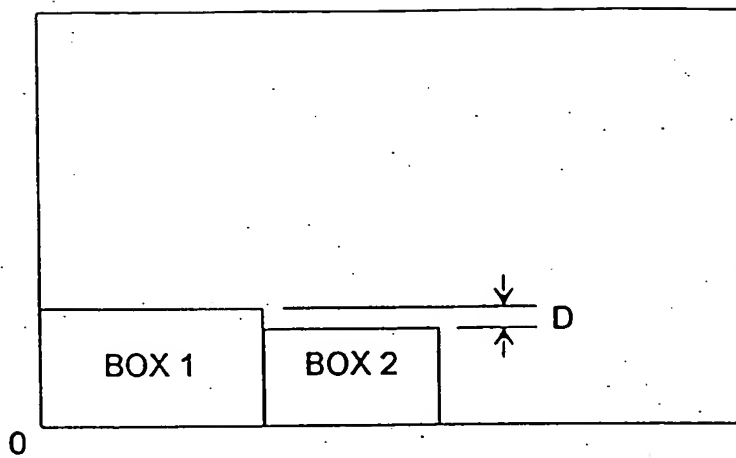
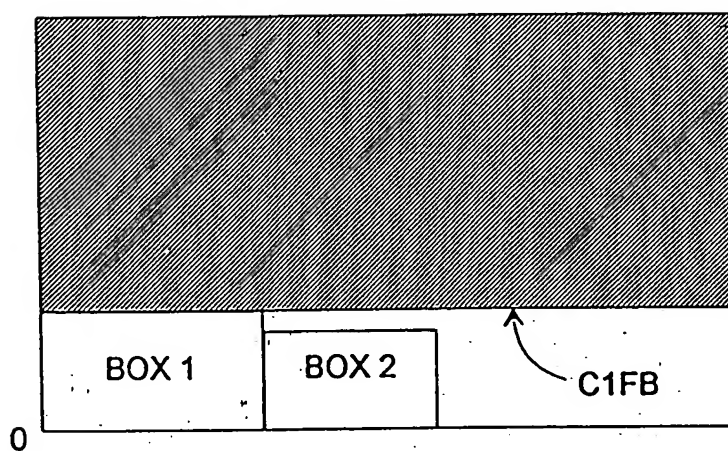
**FIG. 25**



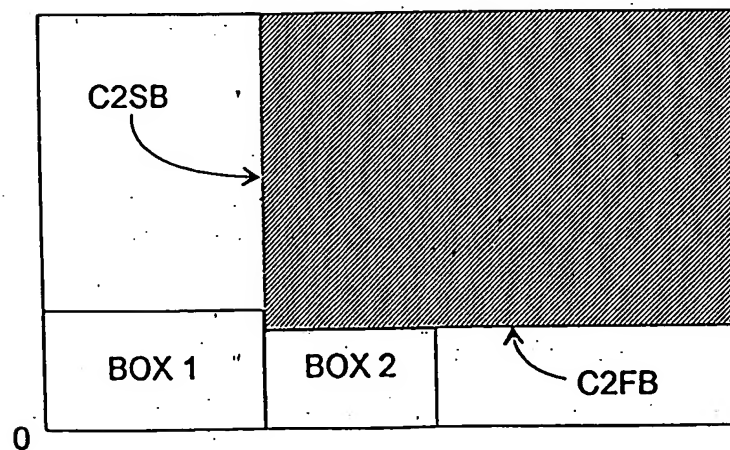
ALTERNATIVE SELECTION SEQUENCES

**FIG. 26**

BOX SUPPORTING RELATIONSHIP  
TREE**FIG. 27****FIG. 28**

**FIG. 29A****FIG. 29B**

CORNER 1

**FIG. 29C**

CORNER 2

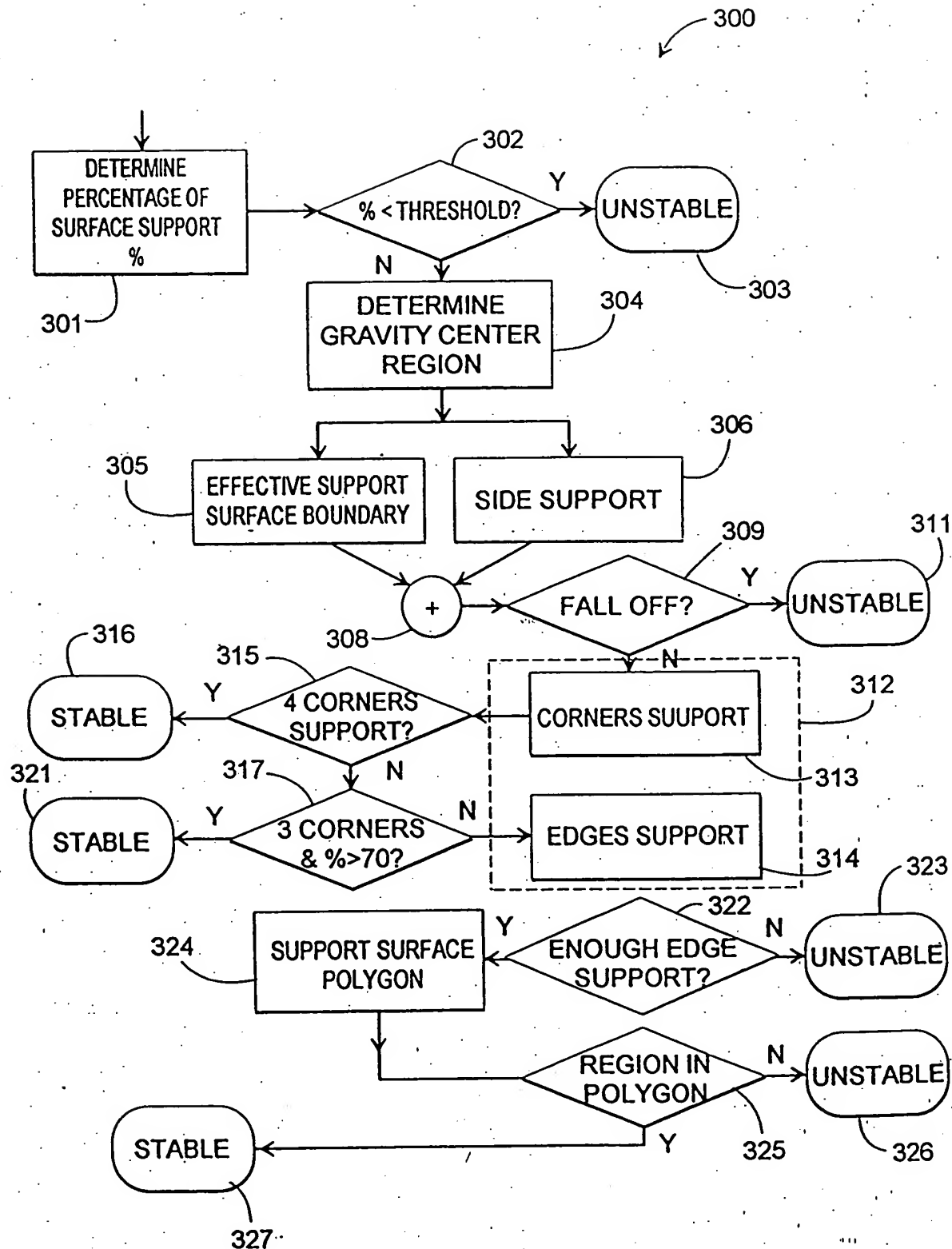
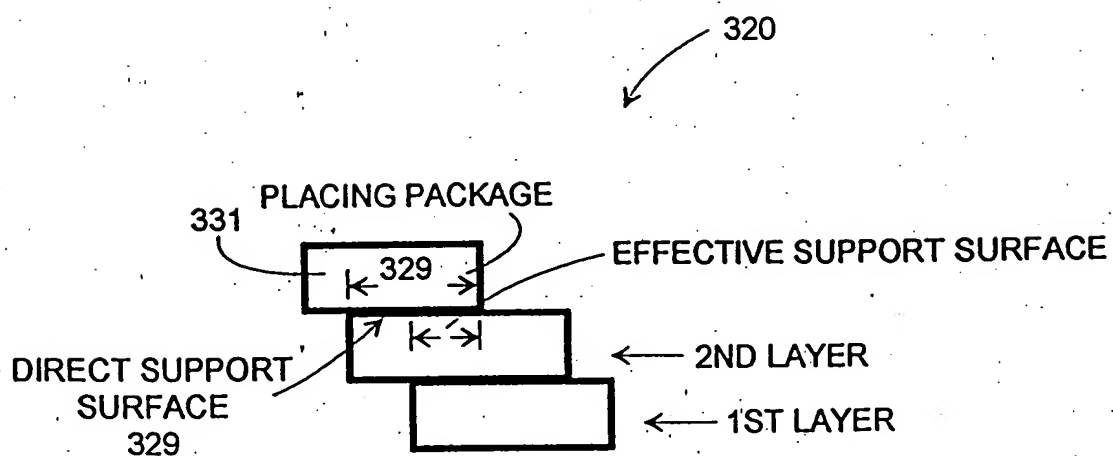
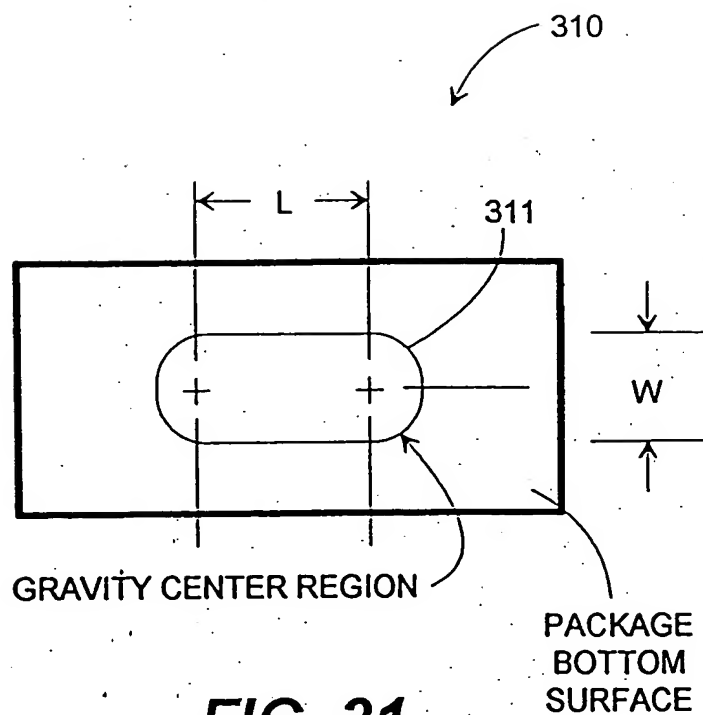
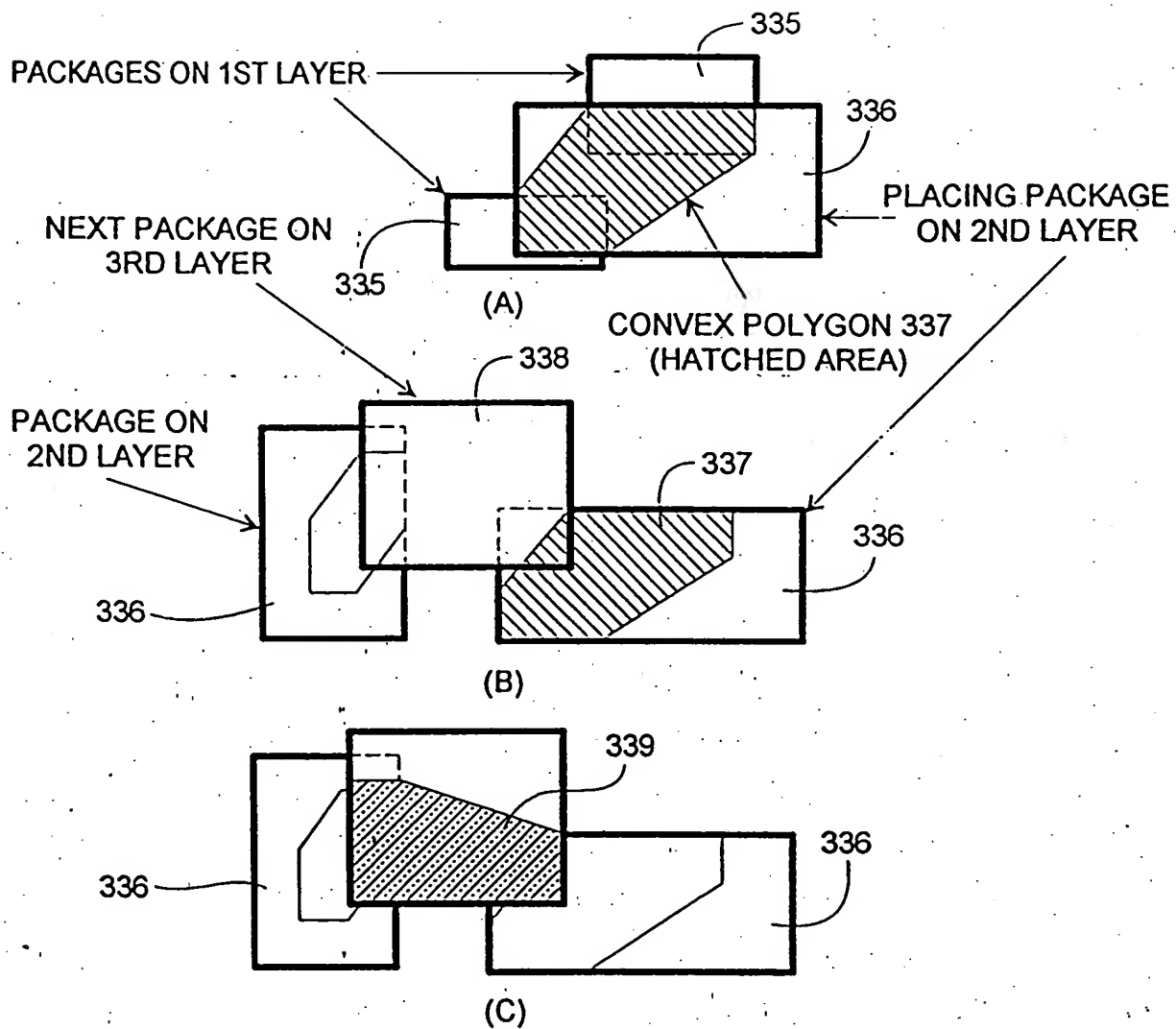


FIG. 30



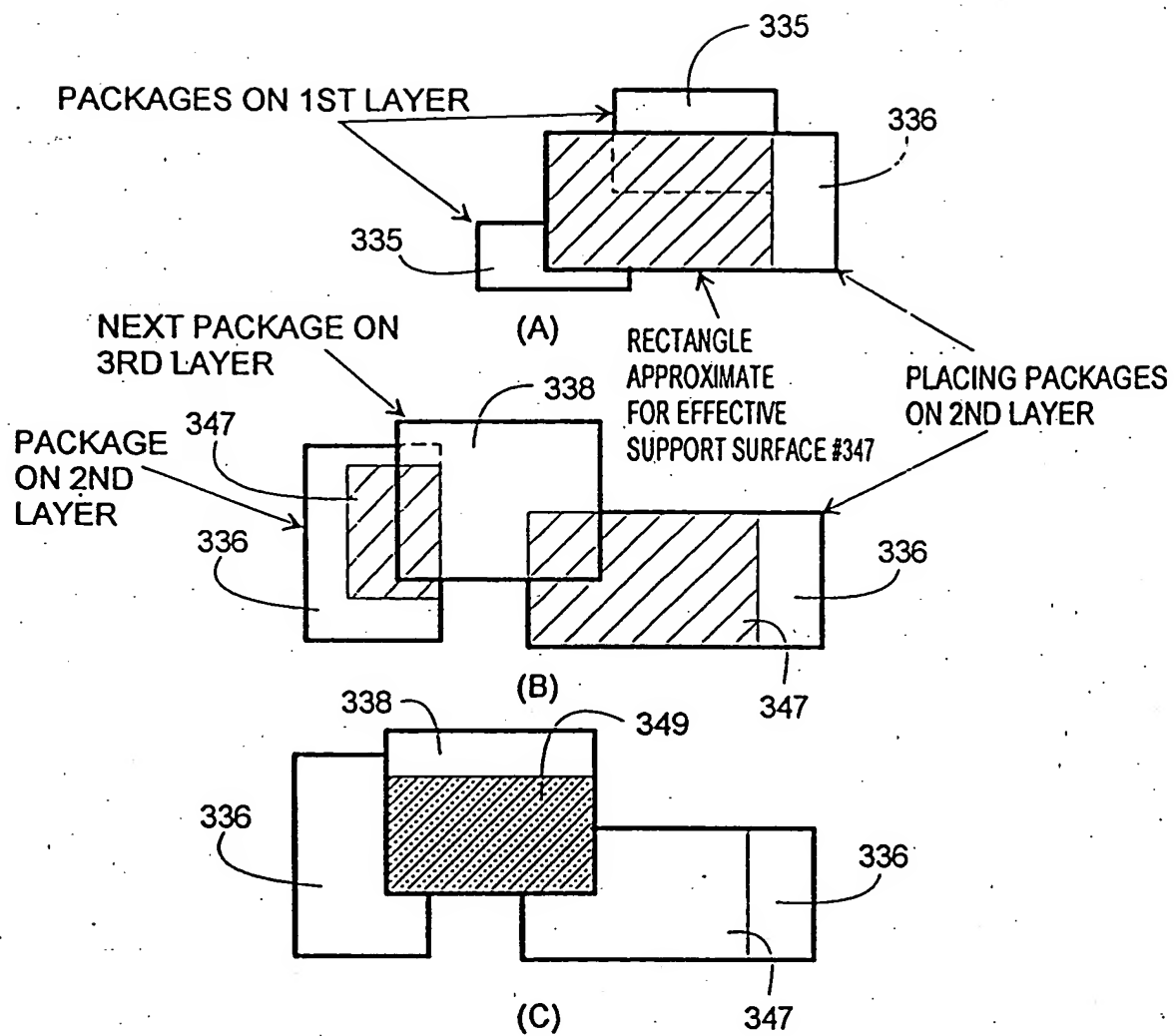
EFFECTIVE SUPPORT SURFACE WHEN SUPPORTED BY SINGLE PACKAGE





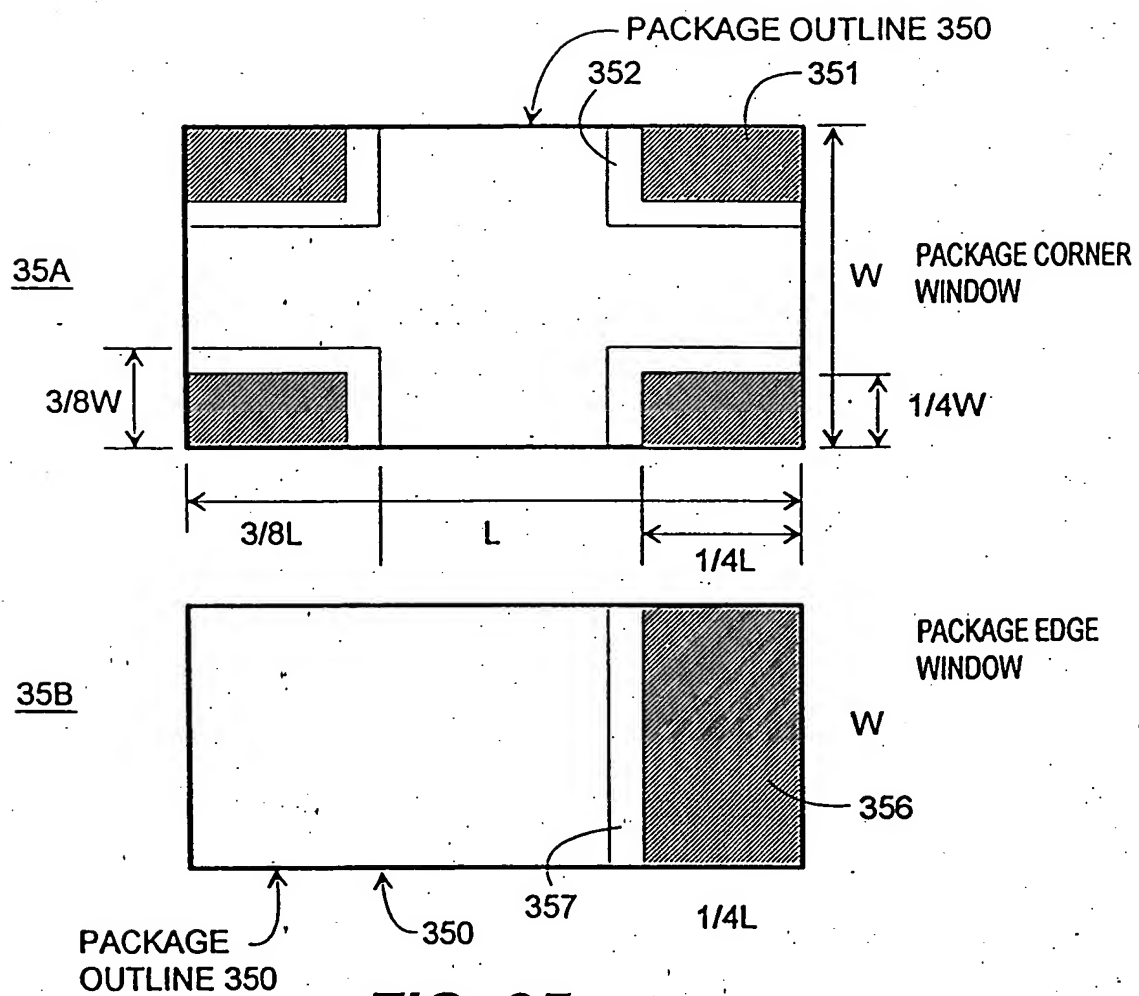
EFFECTIVE SUPPORT SURFACE WHEN SUPPORTED BY MULTIPLE PACKAGES

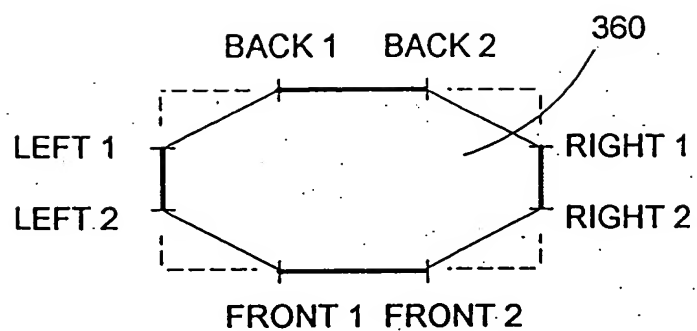
**FIG. 33**



RECTANGLE APPROXIMATE FOR EFFECTIVE SUPPORT SURFACE

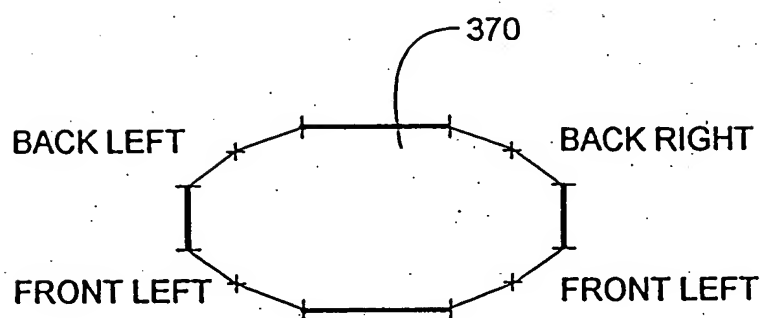
**FIG. 34**

**FIG. 35**



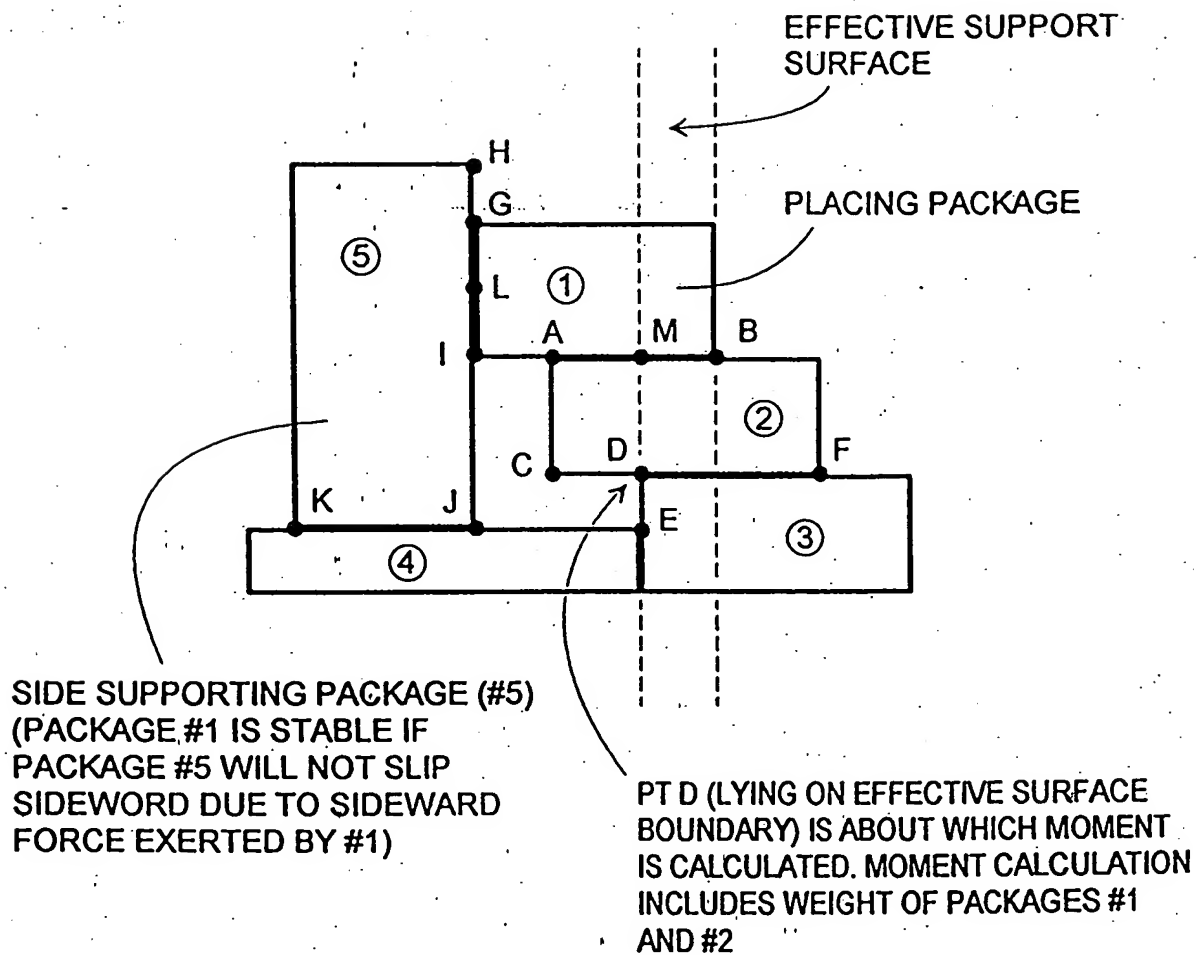
FOUR BOUNDARY EDGES OF A POLYGON

**FIG. 36**



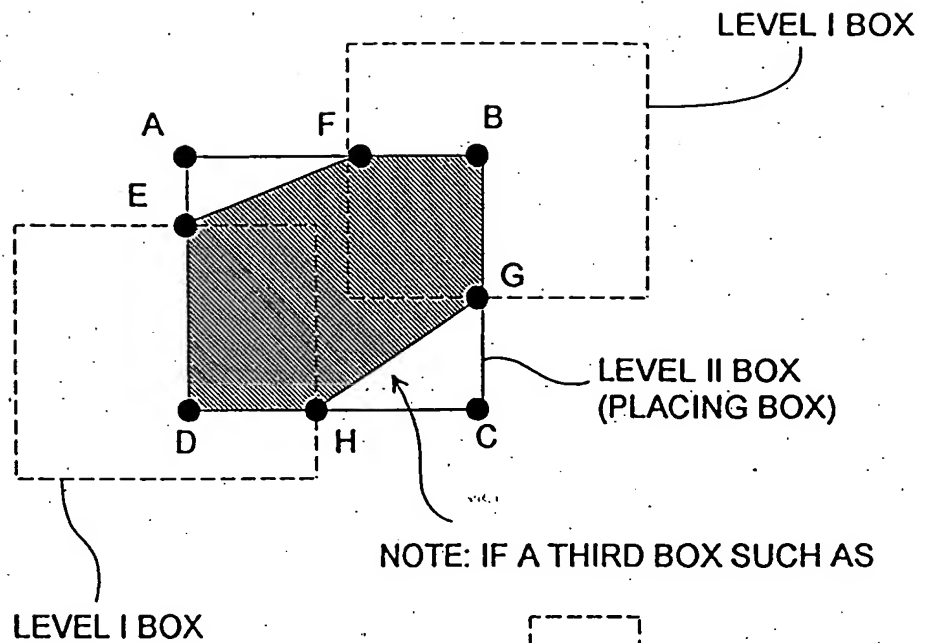
FOUR ADDITIONAL VERTICES

**FIG. 37**

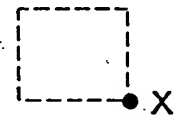


RE: SIDE SUPPORT

**FIG. 38**



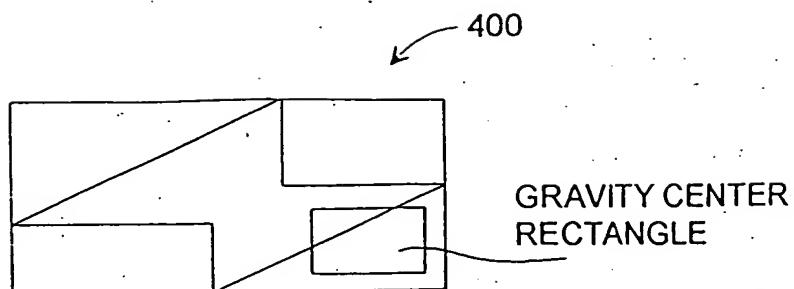
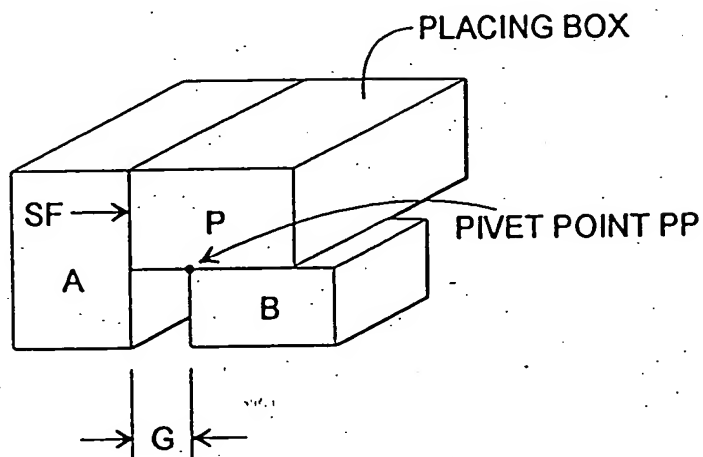
NOTE: IF A THIRD BOX SUCH AS



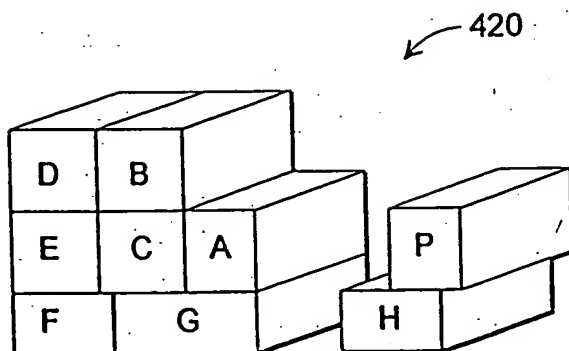
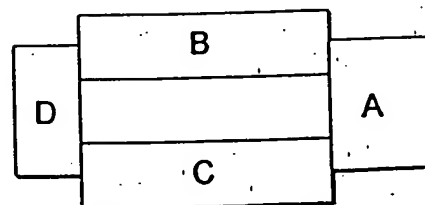
IS LOCATED IN THE "CORNER" DEFINED BY THE TWO LEVEL I BOXES, IF PT "X" EXTENDS OUTSIDE THE DIAGONAL LINE HG, PT X BECOMES AN ADDITIONAL VERTICES (SEE FIG 9)

RE: DIRECT SUPPORT SURFACE POLYGON

**FIG. 39**

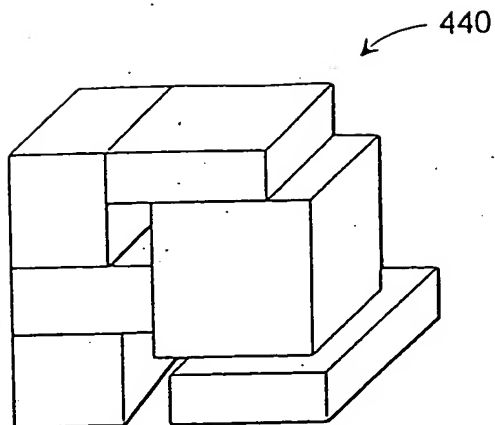
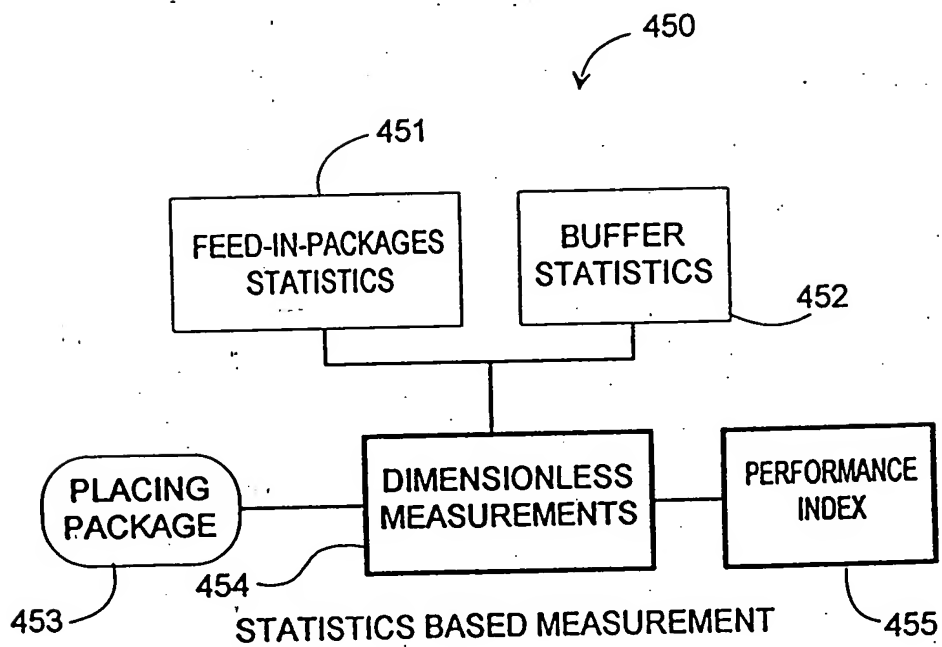
**FIG. 40****FIG. 41**

PACKAGE A PROVIDES SIDE FORCE SF AGAINST PLACING PACKAGE P, WHICH MAY BE SUFFICIENT TO PREVENT PACKAGE P FROM FALLING OFF PACKAGE B ABOUT PIVOT POINT PP.

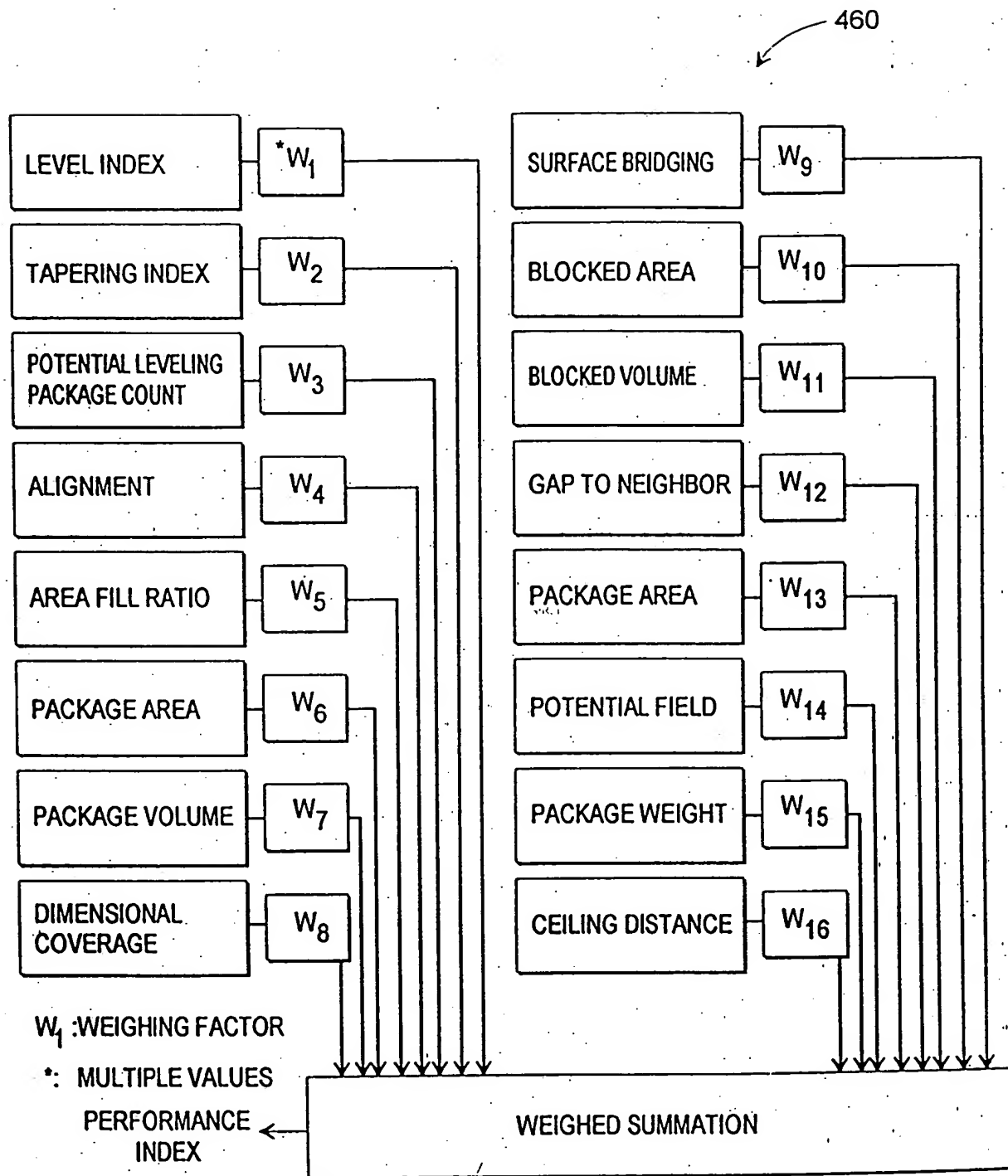
**FIG. 42**

RE: SIDE WEIGHT PROPAGATION

**FIG. 43**

**FIG. 44****FIG. 45**





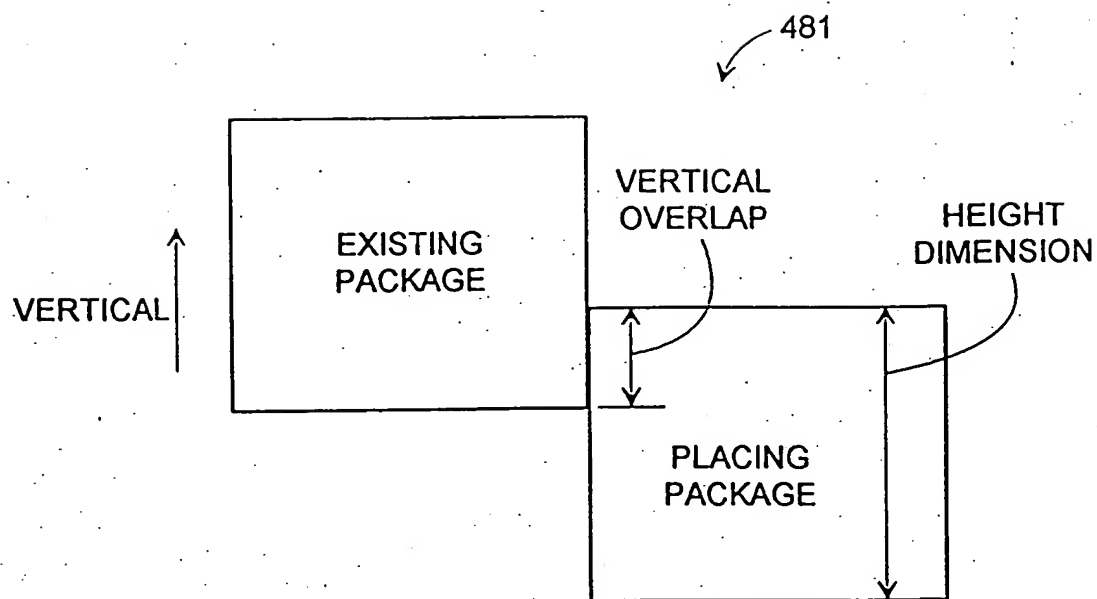
PERFORMANCE INDEX COMPUTATION

**FIG. 46**

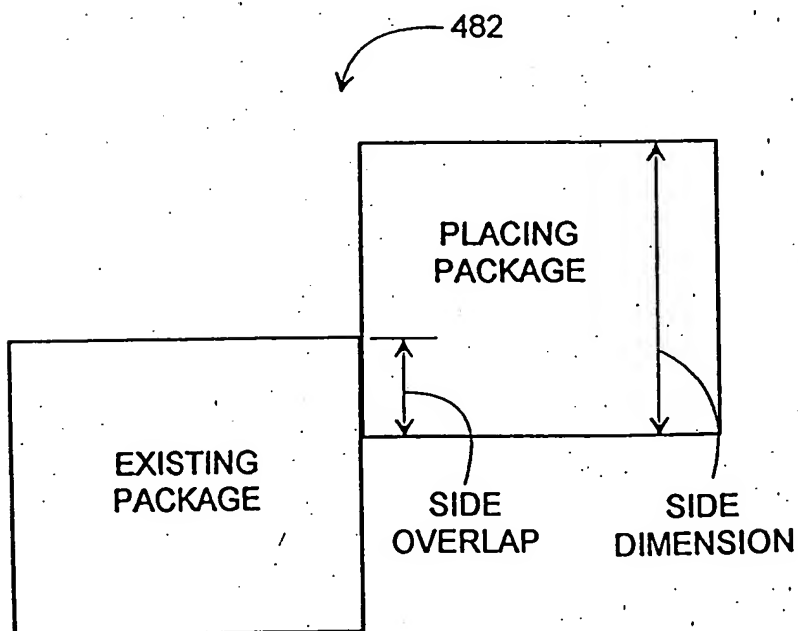
$W_1$	LEVEL INDEX	LEVEL TO ALL NEIGHBORS BONUS:	1600
		LEVEL TO BACK NEIGHBOR BONUS:	1100
		BLOCK BACK PENALTY:	-4000
		ABOVE NEIGHBOR PENALTY:	-2600
		BELOW NEIGHBOR PENALTY:	-600
$W_2$	TAPERING INDEX	TAPERING INDEX PENALTY:	-800 *TAPERING INDEX
$W_3$	{ POTENTIAL LEVEL PACKAGES:		100 *POTENTIAL LEVELING PACKAGES COUNT (APPLICABLE WHEN START A NEW SHELF OR SUB-SHELF)
$W_6$	{ PACKAGE GROUP AREA:		50 *VOLUME/AVERAGE VOLUME (APPLICABLE WHEN STARTING NEW SHELF, PACKAGE IS NEAR BOUNDARY, OR PACKAGE TO COVER A GAP, ETC.)
$W_7$	{ PACKAGE GROUP VOLUME:		50 *VOLUME/APPLICABLE VOLUME (APPLICABLE WHEN STARTING NEW SHELF, PACKAGE IS NEAR BOUNDARY, OR PACKAGE TO COVER A GAP, ETC.)
$W_8$	{ DIMENSIONAL COVERAGE RATION BONUS:		400 *DIMENSIONAL COVERAGE RATIO (FRONT/BACK AND LEFT/RIGHT)
$W_4$	{ NEIGHBOR ALIGNMENT BONUS:		100 *NUMBER OF ALIGNMENTS
$W_5$	{ AREA FILL BONUS:		200 *CORNER AREA FILL RATIO (APPLICABLE FOR SMALL CORNER)
$W_9$	{ SURFACE BRIDGE:		50 *NUMBER OF SURFACE BRIDGING * NUMBER OF TOWERING INDEX
$W_{11}$	{ BLOCK VOLUME PENALTY:		-60 *BLOCKED VOLUME/AVERAGE VOLUME
$W_{10}$	{ BLOCK AREA PENALTY:		-60 *BLOCKED AREA/AVERAGE AREA
$W_{13}$	{ PACKAGE OLD AGE BONUS:		8 *PACKAGE AGE (APPLICABLE WHEN AGE IS ABOVE AN AGE THRESHOLD SUCH AS 10)
$W_{15}$	{ PACKAGE WEIGHT BONUS/PENALTY:		400 * (PACKAGE WEIGHT - WEIGHT THRESHOLD) /((MAX WEIGHT - WEIGHT THRESHOLD) * DISTANCE TO HEIGHT THRESHOLD / MAXIMUM DISTANCE (APPLICABLE WHEN PACKAGE WEIGHT IS ABOVE WEIGHT THRESHOLD)
$W_{12}$	{ NEIGHBOR GAP PENALTY:		-800 *CORNER AND TOP GAPS/ AVERAGE PACKAGE WIDTH
$W_{14}$	{	CORNER HEIGHT:	-2000 #CORNER HEIGHT *PALLET HEIGHT
		CORNER BACK DISTANCE PENALTY:	-60 *CORNER DISTANCE TO BACK BOUNDARY *PALLET DEPTH / MAX(PALLET DEPTH, PALLET LENGTH)
		CORNER SIDE DISTANCE PENALTY:	-60 *CORNER DISTANCE TO LEFT BOUNDARY *PALLET LENGTH / MAX(PALLET DEPTH, PALLET LEGTH)
$W_{16}$	{ DISTANCE TO CEILING PENALTY:		-800 *DISTANCE TO CEILING/ AVERAGE PACKAGE HEIGHT (APPLICABLE WHEN PACKAGE IS ON THE TOP LAYER OF THE STACK)

APPENDIX OF WEIGHING FACTORS  $W_i$  IN PERFORMANCE INDEX (SEE FOG 46)

**FIG. 47**



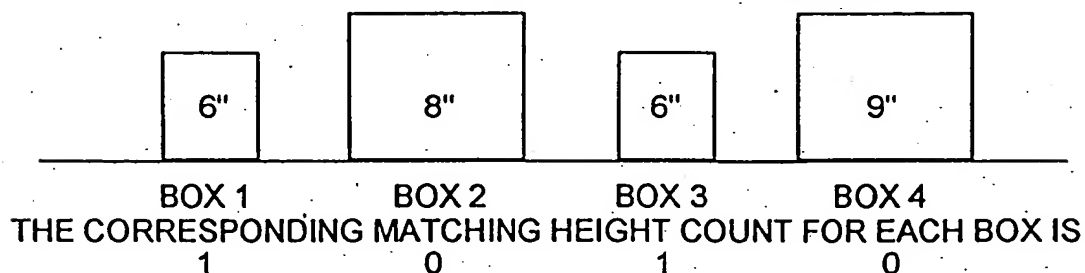
FRONT VIEW

**FIG. 48A**

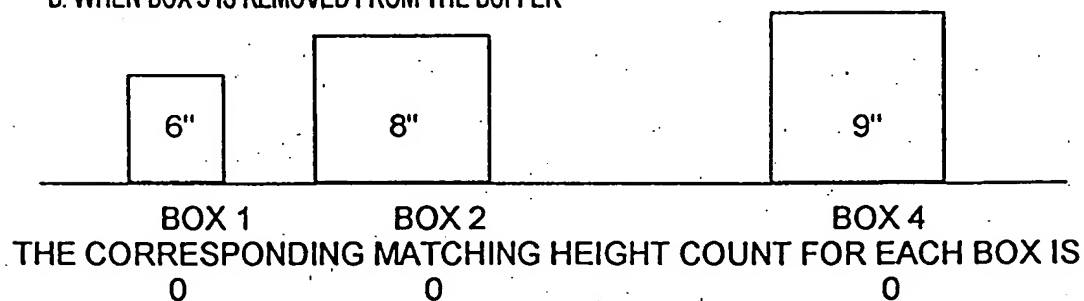
TOP VIEW (BIRD'S EYE VIEW)

**FIG. 48B**

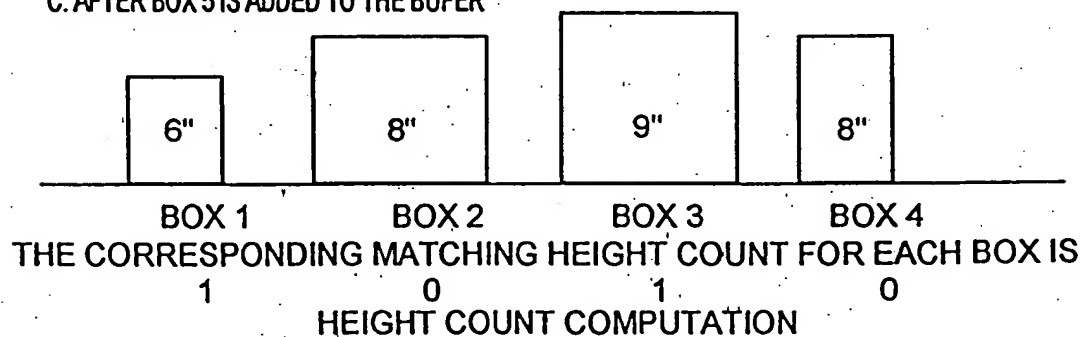
A: INITIALLY IN BUFFER THERE ARE 4 BOXES WHOSE HIEGHT ARE AS SHOWN IN THE FIGURE



B: WHEN BOX 3 IS REMOVED FROM THE BUFFER

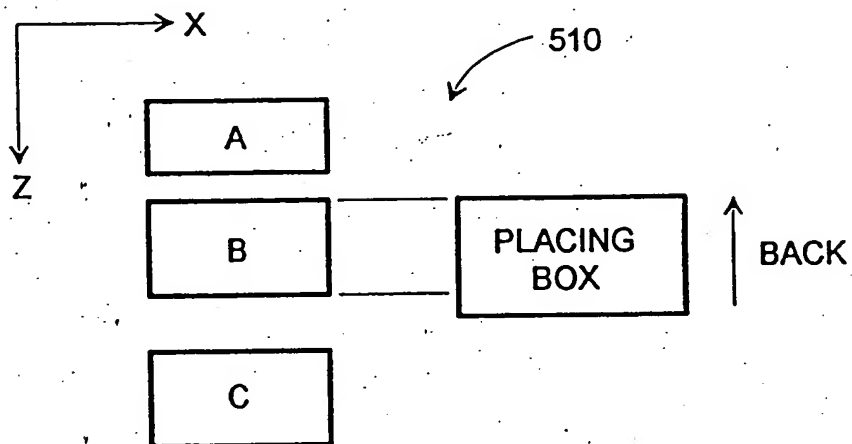
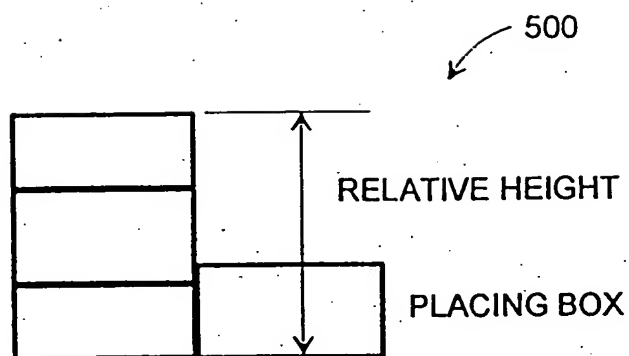


C: AFTER BOX 5 IS ADDED TO THE BUFER



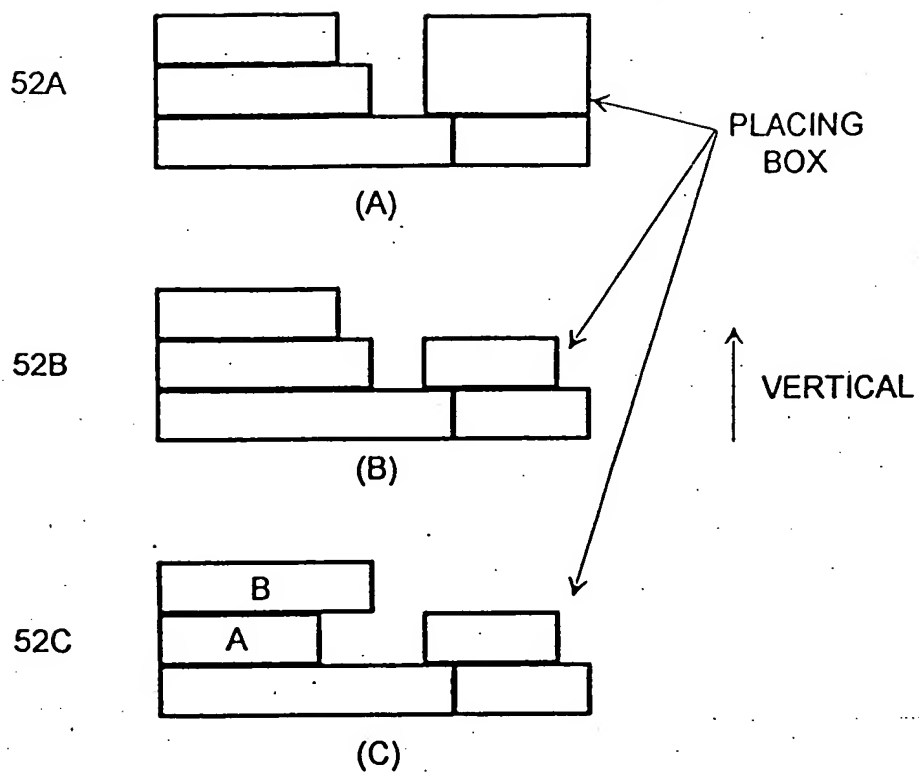
**FIG. 49**

RELATIVE HEIGHT CHECK

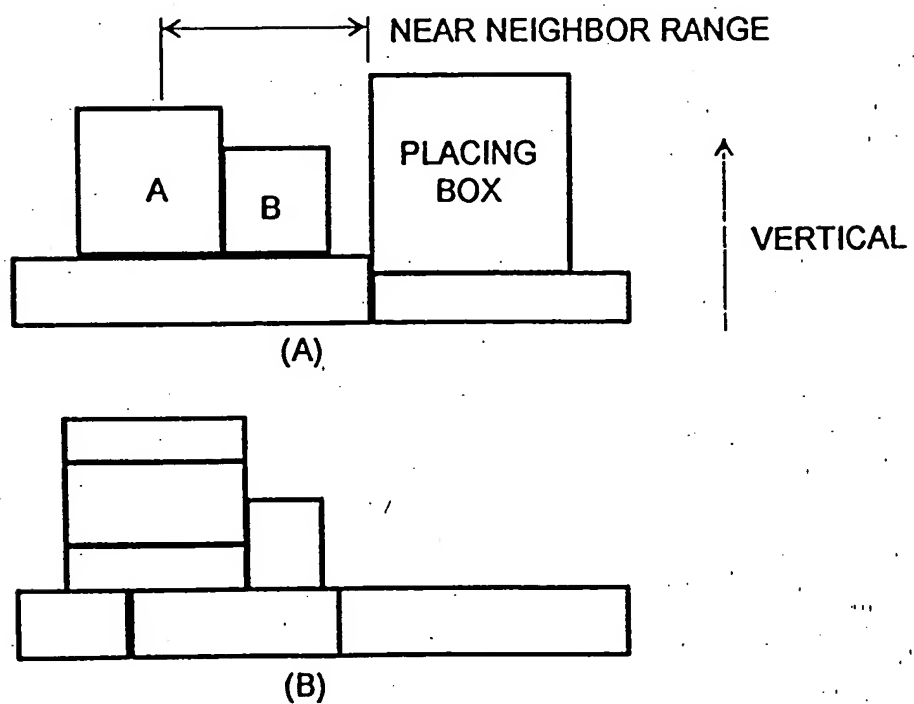
**FIG. 50**

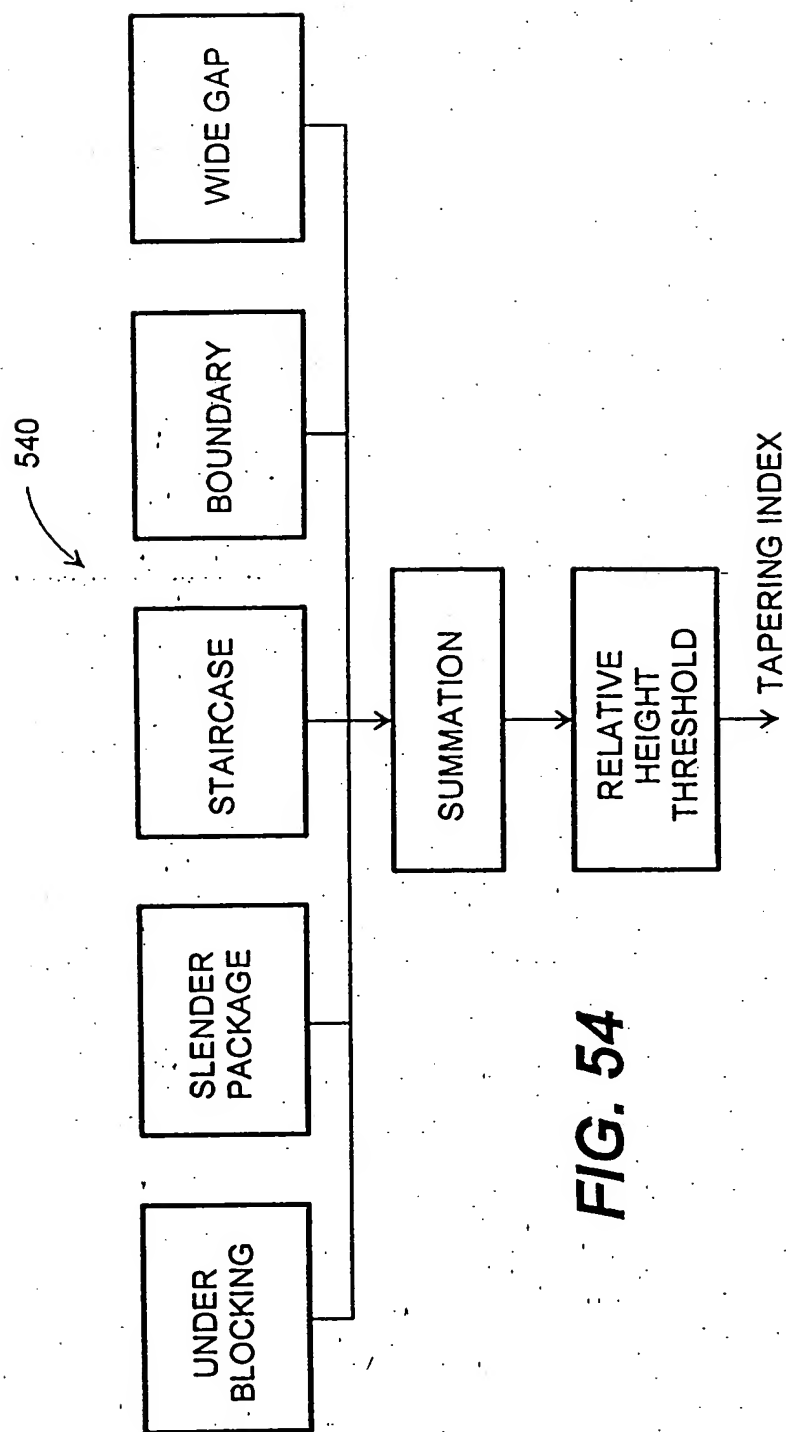
NEIGHBOR BOX HAS SIDE OVERLAP WITH PLACING BOX

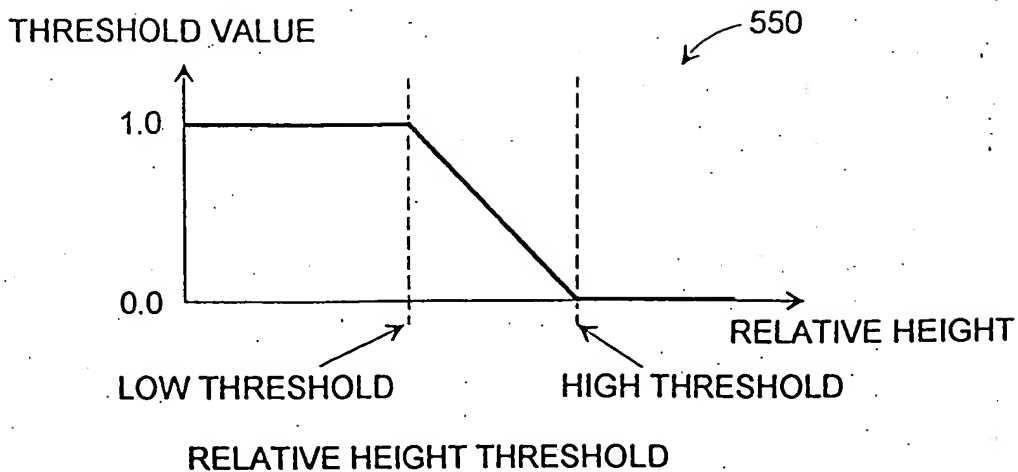
**FIG. 51**



PLACING BOX LEVELS WITH NEIGHBOR

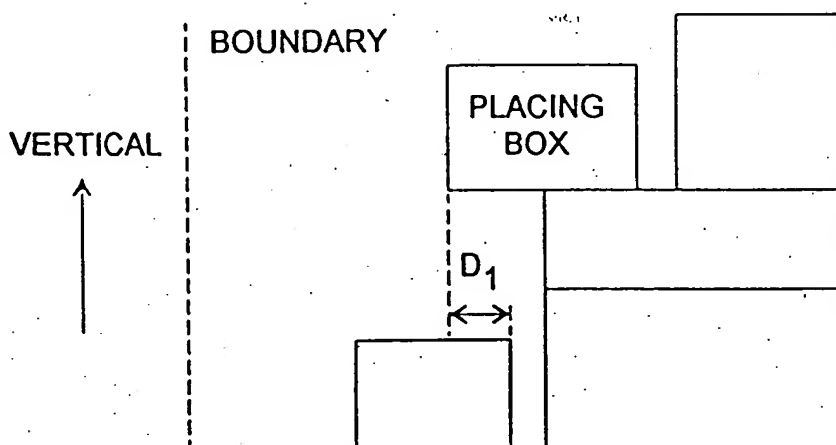
**FIG. 52****FIG. 53**

**FIG. 54**

**FIG. 55**BLOCK A LOWER :CORNER

APPENDIX B:

RULE1: EXCESSIVEBLOCKING



$W_A$  -AVERAGEWIDTH OF ALL BOXES IN STACK AND BUFFER

$D_1$  -MINIMUM BLOCKED HORIZONTAL LENGTH IN LOWER CORNER SURFACES

IF:

$$D_1 > W_A / 3$$

THEN:

$$\text{TAPERING INDEX: } D_1 / (W_A / 3)$$

STACKING RULES

**FIG. 56**



BLOCK A LOWER CORNER:RULE 2: BLOCK A POSSIBLE UNDER PLACEMENT

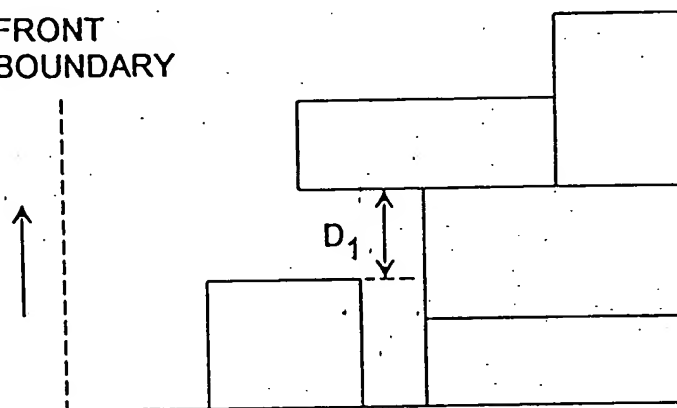
$H_A$  - AVERAGE HEIGHT OF ALL BOXES IN STACK AND BUFFER

$W_M$  - MINIMUM WIDTH OF ALL BOXES IN BUFFER

$W_A$  - AVERAGE WIDTH OF ALL BOXES IN STACK AND BUFFER

$A_A$  - AVERAGE AREA OF ALL BOXES IN STACK AND BUFFER

FRONT  
BOUNDARY



IF:

BEFORE BOX IS PLACED:

IT IS POSSIBLE TO PLACE  
A BOX IN A LOWER CORNER  
AND

$D_1 < 1.7H_A$  AND

AFTER BOX IS PLACED

MOST LIKELY IT IS NOT  
POSSIBLE TO PLACE BOX  
ON TOP OF UNDERSURFACE

CONDITION FOR BEING MOST POSSIBLE TO  
PLACE A BOX IN A LOWER CORNER:

CORNER'S MIN. DIMENSION  $\geq W_A$  AND

CORNER'S MIN. DIMENSION  $\geq W_M$  AND

CORNER'S MIN. SURFACE DIMENSION  $> 0.6W_A$

AND CORNER'S SURFACE AREA  $> 0.6A_A$

THEN

TAPER INDEX 1

CONDITION FOR BEING MOST LIKELY NOT POSSIBLE TO PLACE BOX  
IN LOWER CORNER AFTER PLACING BOX

CORNER'S UNBLOCKED MIN. DIMENSION  $< 0.9 W_A$  OR

CORNER'S UNBLOCKED MIN. DIMENSION  $< W_M$  OR

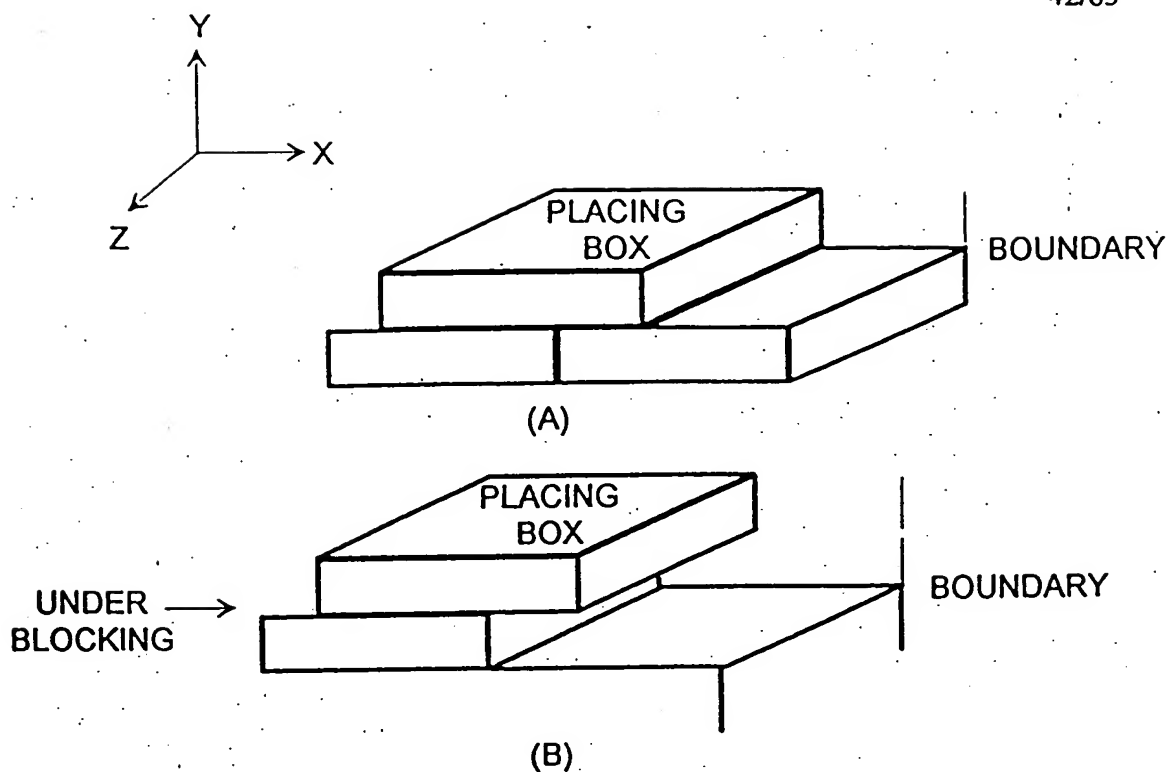
CORNER'S UNBLOCKED MIN. SURFACE DIMENSION  $< 0.6 W_A$  OR

CORNER'S UNBLOCKED SURFACE AREA  $< 0.6 A_A$

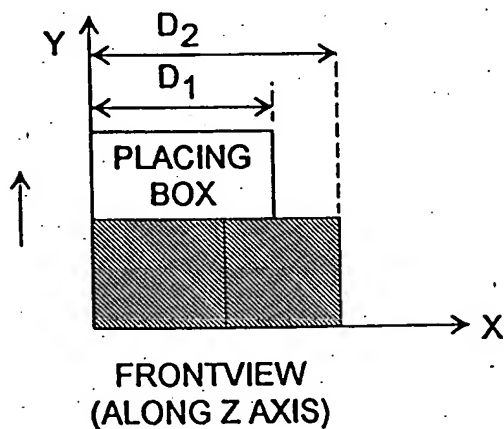
$D_1$  - SHOULDER HEIGHT

STACKING RULES

**FIG. 57**



BOUNDARY CORNER CHECK

**FIG. 58****SLENDER BOX:****RULE 3: SLENDER BOX AT CORNERSTONE**

IF  
BOX IS PLACED AT CORNERSTONE  
POSITION AND  $D_1 < W_A$  AND  
 $D_2 > W_A$

THEN  
TAPERING INDEX: 2

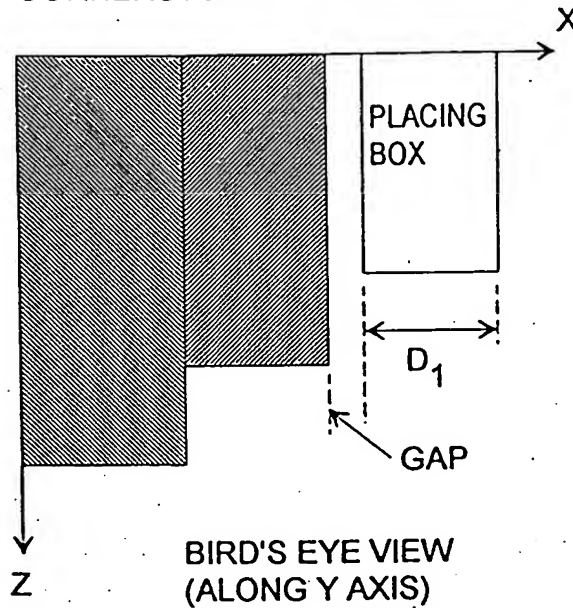
$W_A$  - AVERAGE WIDTH OF ALL BOXES IN STACK AND BUFFER  
CORNERSTONE - VERY FIRST BOX IN A NEW SHELF  
 $D_1$  - TOTAL WIDTH OF A LEVELING BOX GROUP  
 $D_2$  - SUPPORTING SURFACE SPAN

STACKING RULES

**FIG. 59**

## SLENDER BOX:

RULE 4: A SLENDER BOX  $B$  IS POSITIONED AT LOCATIONS OTHER THAN CORNERSTONE



IF

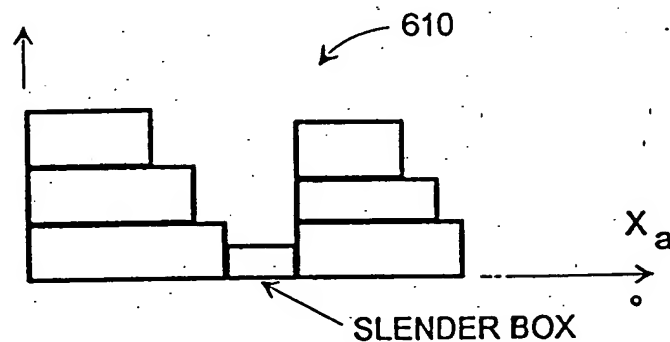
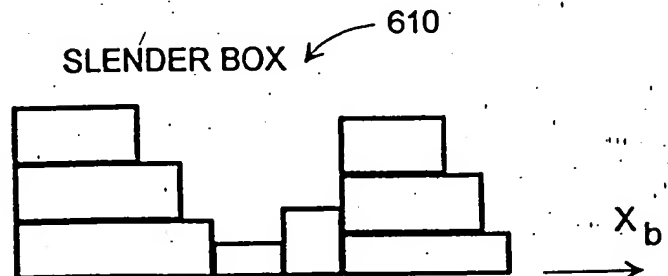
$D < 0.7 W_A$  AND  
(PLACING BOX IS NOT LEVEL  
WITH ITS NEIGHBORS OR THE  
 $GAP > W_A / 3$ ) AND  
THE SUPPORTING SURFACE  
IS WIDER THAN  $D$  AND THE  
PLACING BOX IS NOT NEAR TO  
THE OUTSIDE BOUNDARY

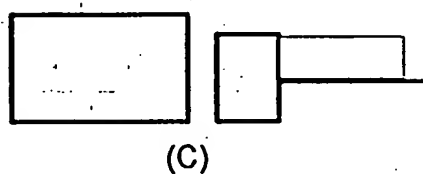
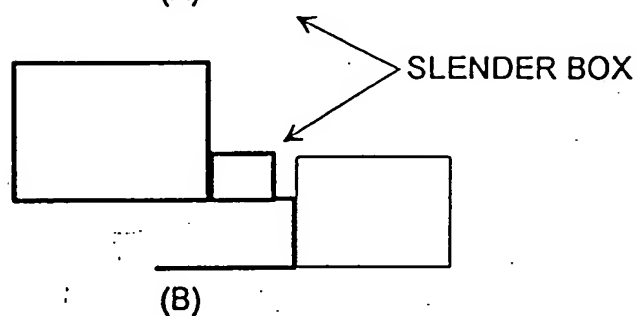
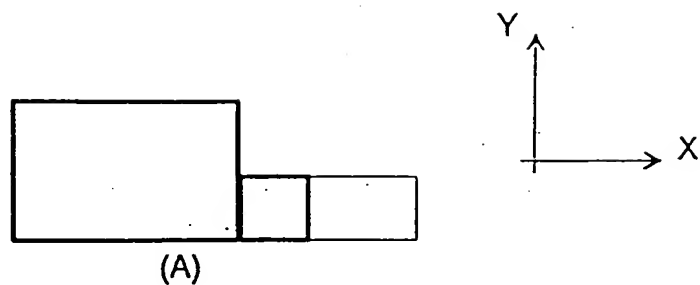
THEN

TAPER INDEX:  $2 \times (1 - D_1 / W_A)$

$W_A$  - AVERAGE WIDTH OF ALL BOXES IN STACK AND BUFFER  
 $D_1$  - WIDTH OF A POSSIBLE LEVELING BOX GROUP

## STACKING RULES

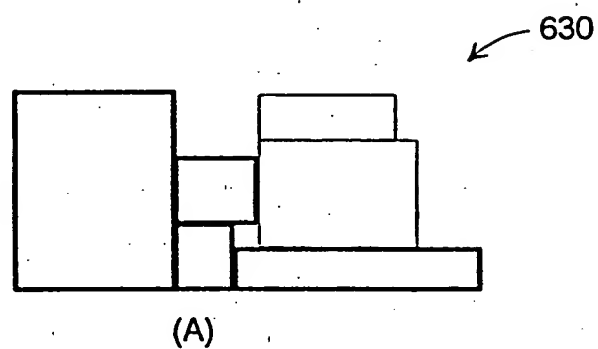
**FIG. 60****FIG. 61A****FIG. 61B**



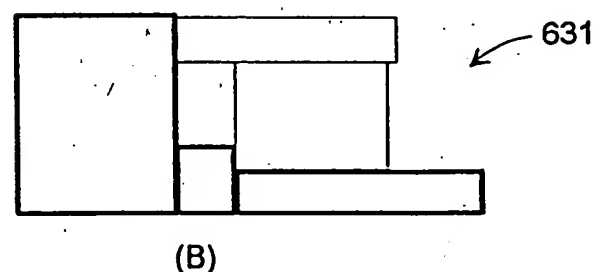
FIND A MATCHING BOX

**FIG. 62**

**FIG. 63A**



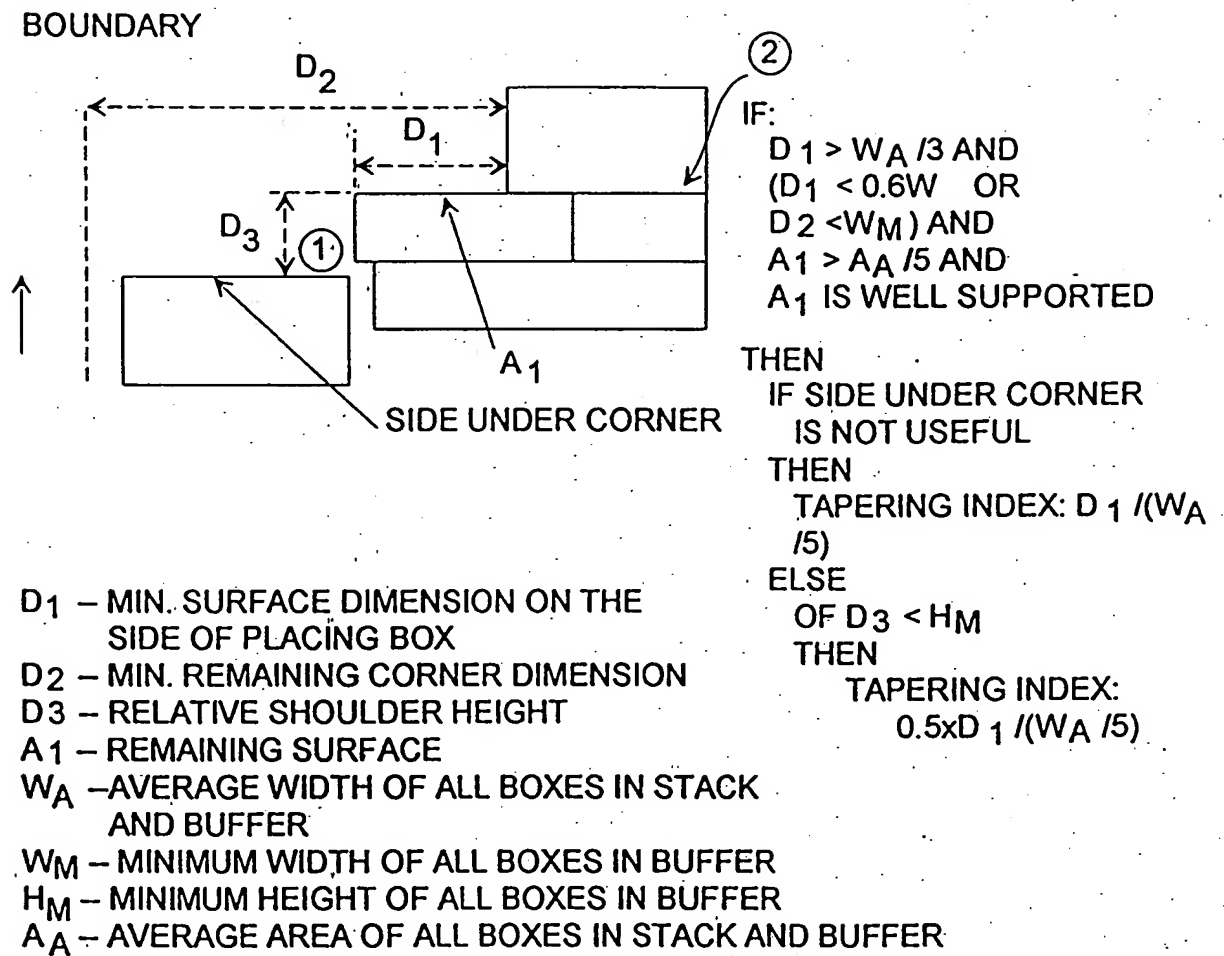
**FIG. 63B**



SLENDER BOX AMPLIFIES A GAP

STAIRCASE:

## RULE 5: POTENTIAL STAIRCASE ON THE SIDE

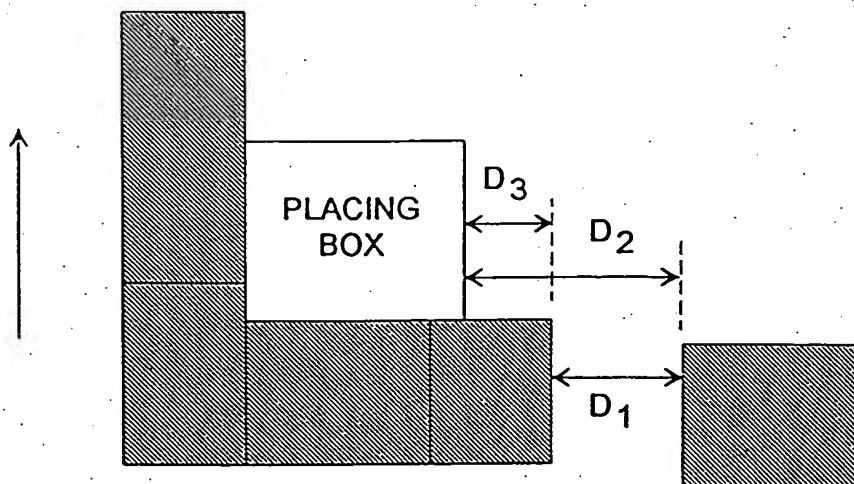


STACKING RULES

**FIG. 64**

**STAIRCASE:**

**RULE 6: THERE EXISTS A BIG GAP IN THE MIDDLE OF A NEARBY CORNER SURFACES AND CURRENT PLACEMENT LEAVES USELESS SPACE ON THE SAME SIDE**



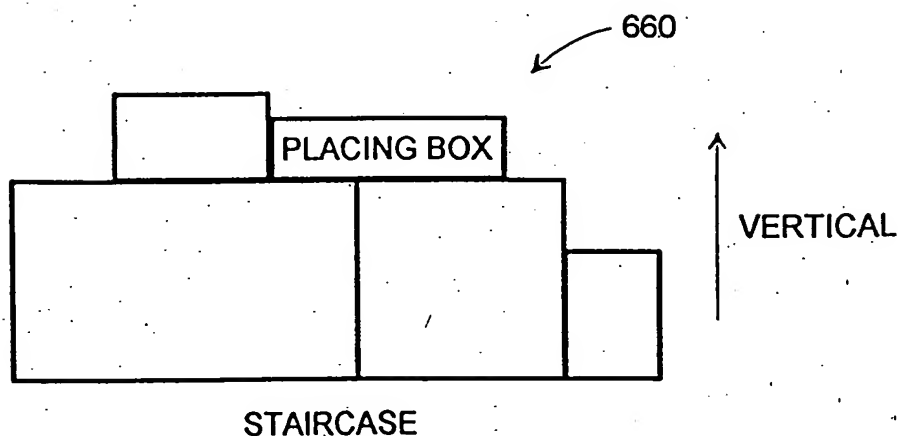
IF

$D_1 < W_A$  AND  
 $D_1 > W_A / 2$  AND  
 $D_2 > 0.7 W_A$  AND  
 $D_3 > 1"$  AND  
 $D_3 < W_A / 2$

THEN

TAPERING INDEX:  
 $D_3 / (W_A / 3)$

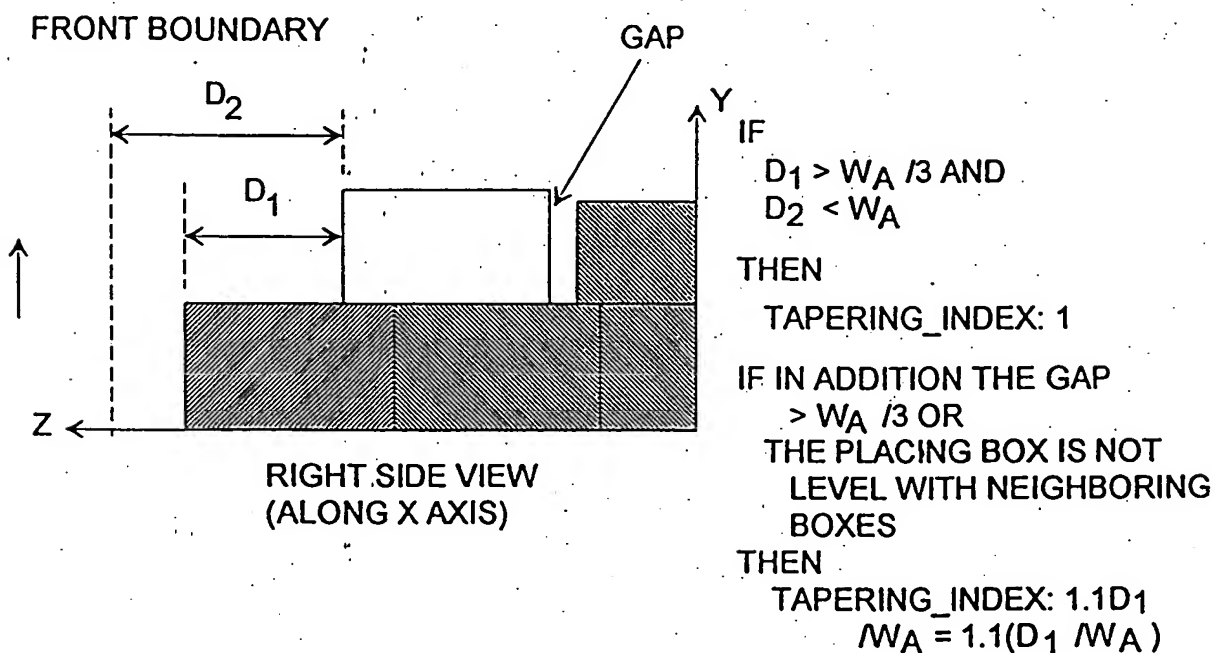
$D_1$  -- GAP IN CORNER SURFACE ON THE SIDE  
 $D_2$  -- DISTANCE TO NEXT CORNER SURFACE  
 $D_3$  -- MIN. DIMENSION OF REMAINING SURFACE  
 $W_A$  -- AVERAGE WIDTH OF ALL BOXES IN STACK AND BUFFER

**STACKING RULES****FIG. 65****FIG. 66**

670

BOUNDARY:

RULE 7: LEAVE POTENTIALLY UNUSABLE SPACE ON FRONT BOUNDARY

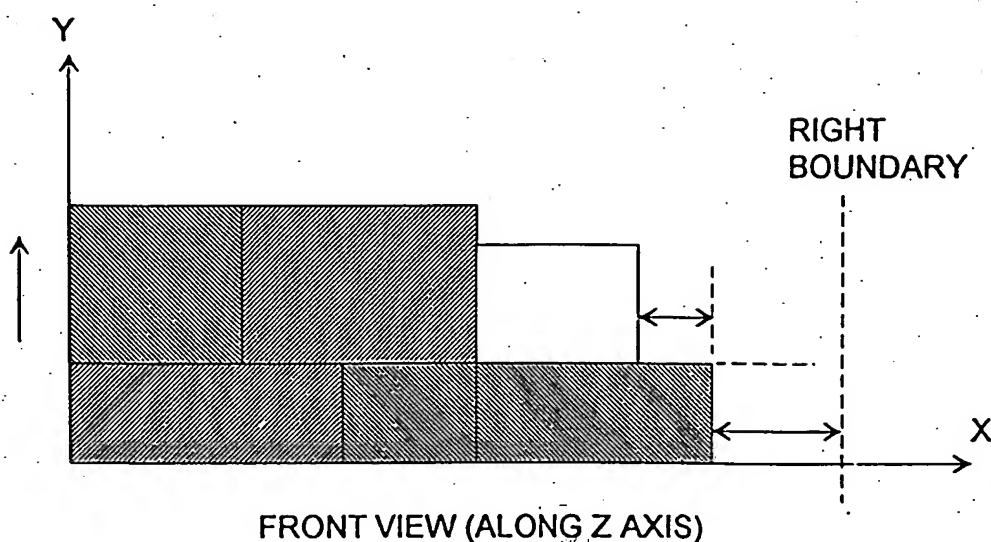
 $D_1$  — MIN. DIMENSION ON REMAINING SURFACES $D_2$  — DISTANCE TO FRONT BOUNDARY $W_A$  — AVERAGE WIDTH OF ALL BOXES IN STACK AND BUFFER

STACKING RULES

**FIG. 67**

BOUNDARY:

RULE 8: TOO MUCH SURFACE SPACE COULD BECOME WASTEFUL  
ON RIGHT BOUNDARY



IF

\*BOX IS CLOSE TO RIGHT BOUNDARY AND  
NO BOX CAN BE PLACED ON THE RIGHT OF  
PLACING BOX TO MATCH ITS HEIGHT AND  
 $D_1 > W_A / 3$

THEN

TAPERING INDEX:  $1.7 \times D_1 / W_A / 3$

\*BOX IS CONSIDERED AS CLOSE TO RIGHT BOUNDARY WHEN

$D_2 < L_A$  OR  
( $D_2 < 1.5 L_A$  AND  
 $D_1 < L_A$  AND  
THE LOWER CORNER ASSOCIATED WITH  $D_2$   
IS NOT USEFUL)

$D_1$  IS THE MINIMUM DIMENSION OF SURFACE AFTER PLACING BOX  
 $D_2$  - DISTANCE TO RIGHT BOUNDARY  
 $L_A$  - AVERAGE LENGTH OF ALL BOXES IN STACK AND BUFFER

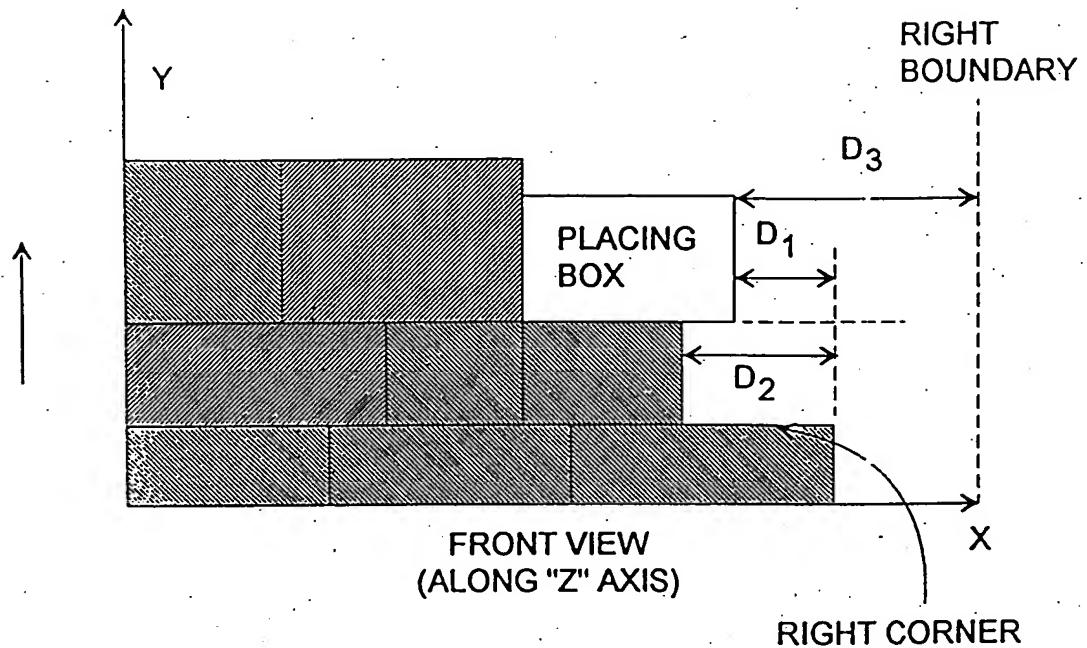
STACKING RULES

**FIG. 68**



**BOUNDARY:**

**RULE 9: BLOCKING RIGHT CORNER AT BOUNDARY SO A POSSIBLE SIDE PLACEMENT MAY BE LOST**



**IF**

\*PLACING BOX IS CLOSE TO RIGHT BOUNDARY  
AND  
NO BOX CAN BE PLACED ON THE RIGHT OF  
PLACING BOX B TO MATCH ITS HEIGHT AND  
 $D_1 > 0.4 W_A$  AND  
RIGHT CORNER MAY BE USEFUL AND  
 $D_2 > 0.75 W_A$

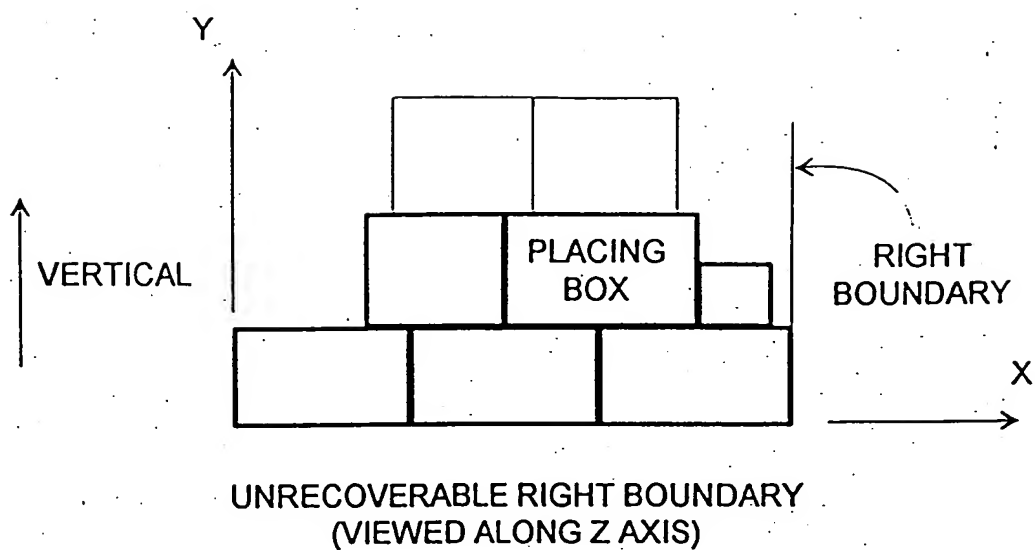
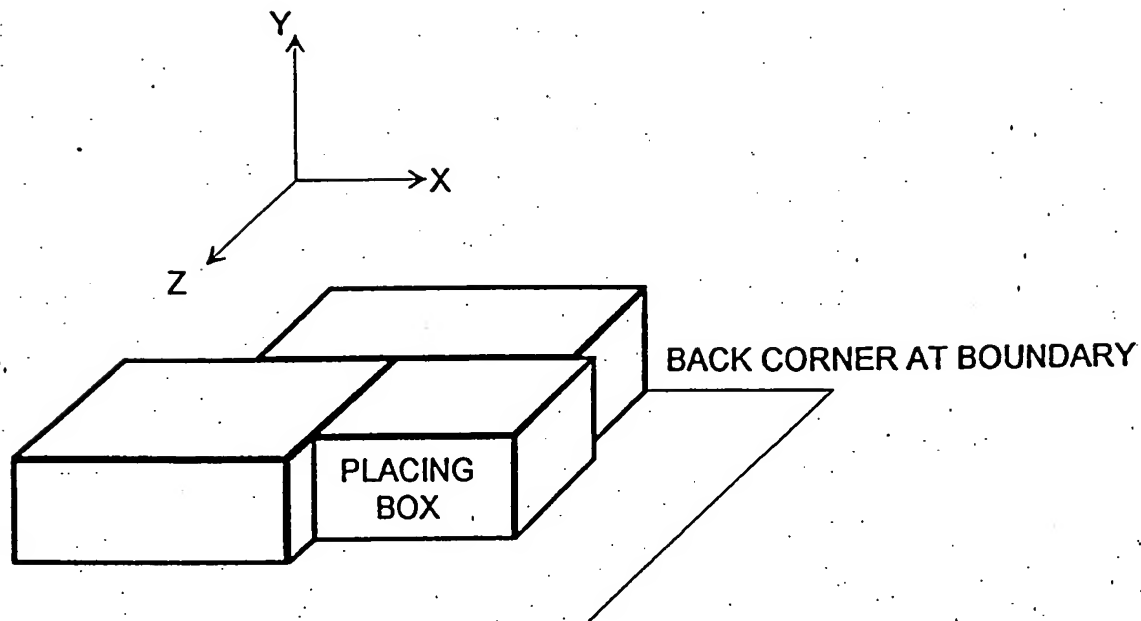
**THEN**

TAPERING INDEX: 1.5

$D_1$  -- MIN. DIMENSION OF UNBLOCKED SURFACE PORTION AT  
RIGHT CORNER  
 $D_2$  -- MIN. SURFACE DIMENSION OF RIGHT CORNER  
 $D_3$  -- DISTANCE TO RIGHT BOUNDARY

\*PLACING BOX IS CLOSE TO RIGHT BOUNDARY WHEN  $D_3 < L_A$   
 $W_A$  - AVERAGE WIDTH OF ALL BOXES IN STACK AND BUFFER  
 $L_A$  - AVERAGE LENGTH OF ALL BOXES INSTACK AND BUFFER

**FIG. 69**

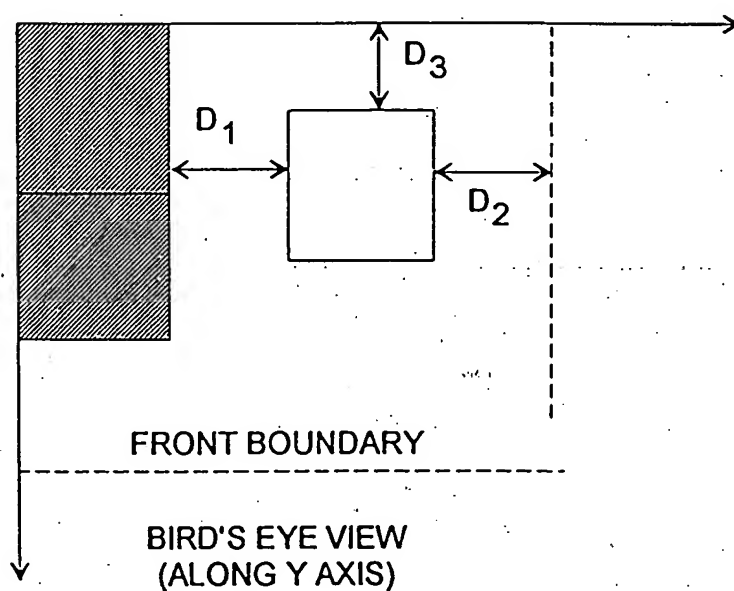
**FIG. 70**

BACK CORNER AT BOUNDARY

**FIG. 71**

## WIDE GAP

RULE 10: EXCESSIVE WIDE GAP WHEN PLACING BOX IS NOT  
NEAR THE FRONT BOUNDARY



$D_1$  - DISTANCE TO LEFT NEIGHBOR

$D_2$  - DISTANCE TO RIGHT CORNER BOUNDARY

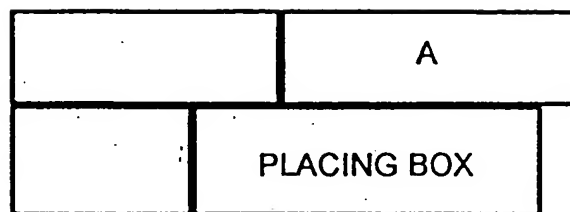
$D_3$  - DISTANCE TO BACK CORNER BOUNDARY

$W_A$  - AVERAGE WIDTH OF ALL BOXES IN STACK AND BUFFER

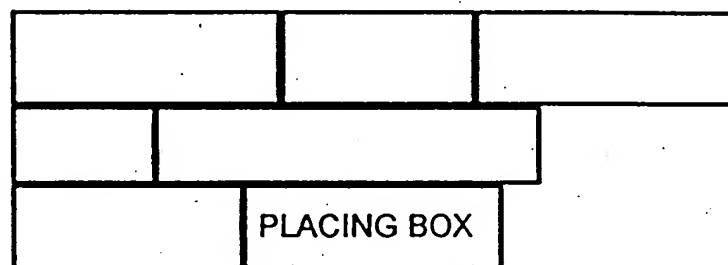
$\min(D_1, D_2)$  - THE LESSER OF  $D_1$  AND  $D_2$

STACKING RULES

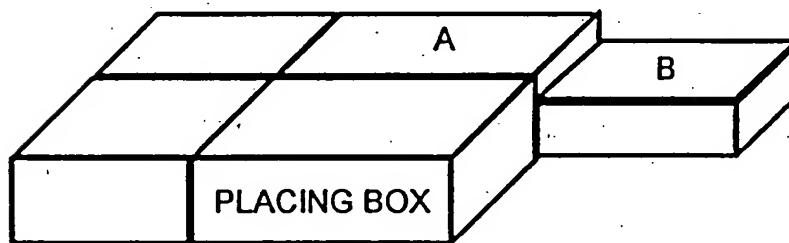
**FIG. 72**



(A)



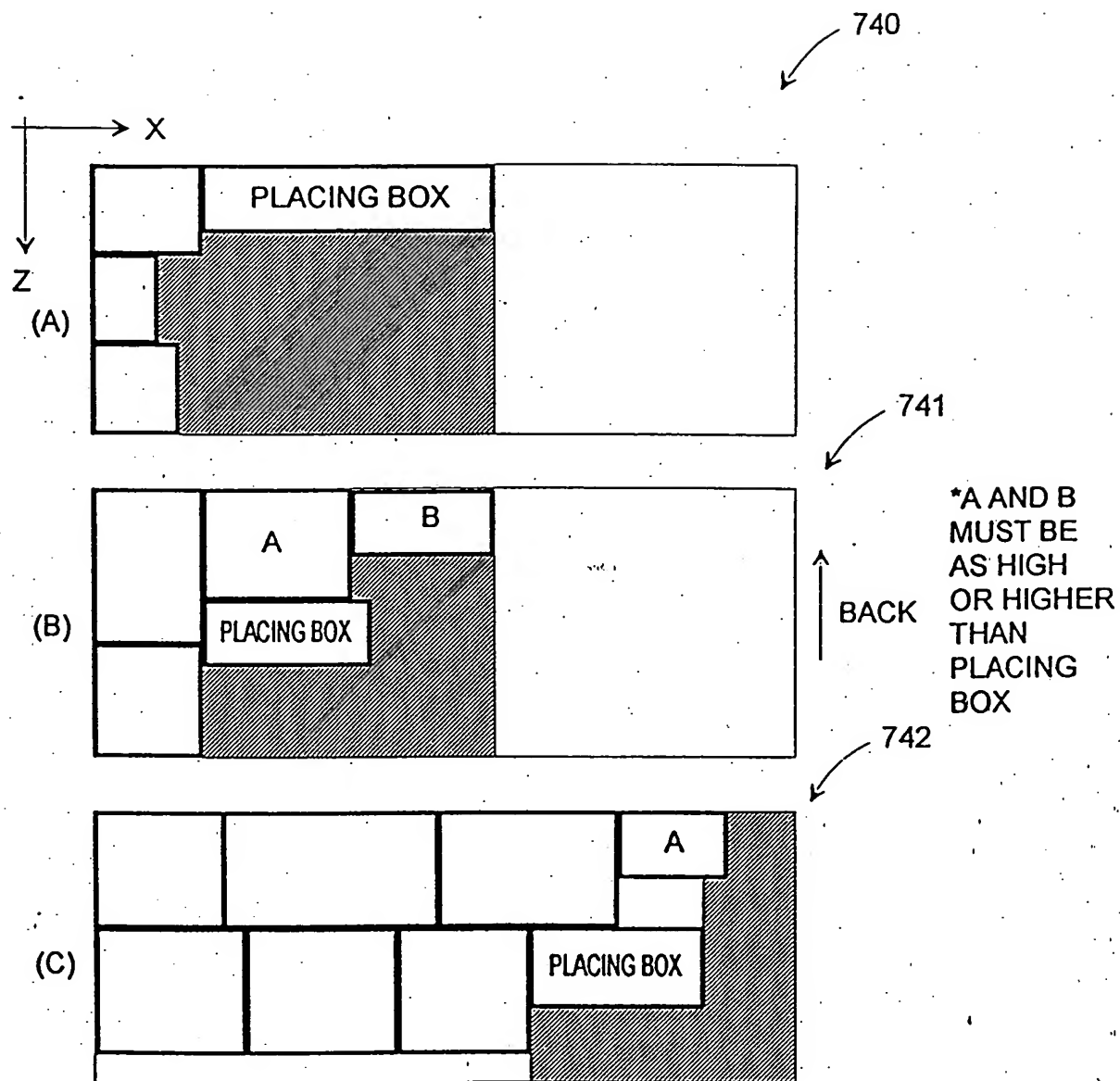
(B)



(C)

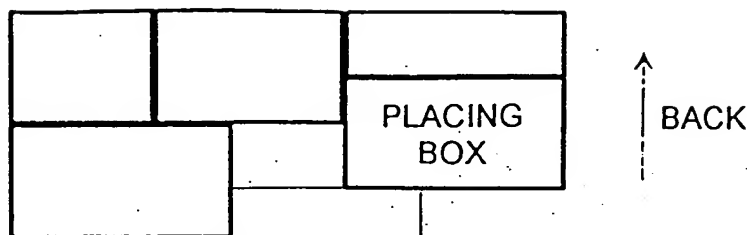
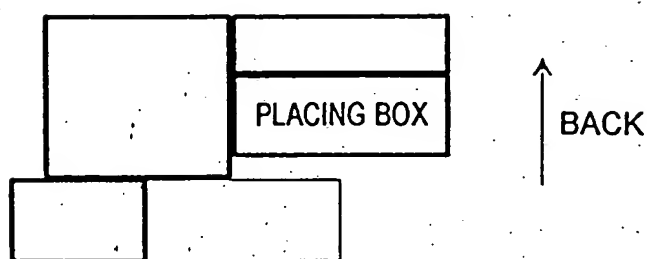
BACK ALIGNMENT

**FIG. 73**

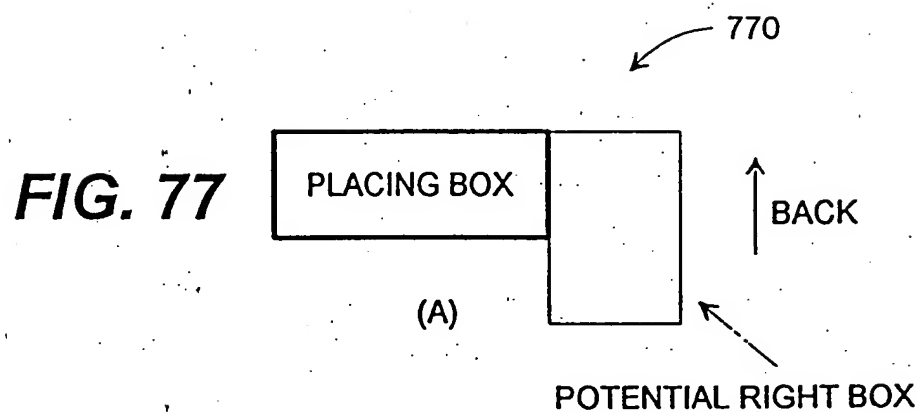


BOX GROUP BOUNDARY

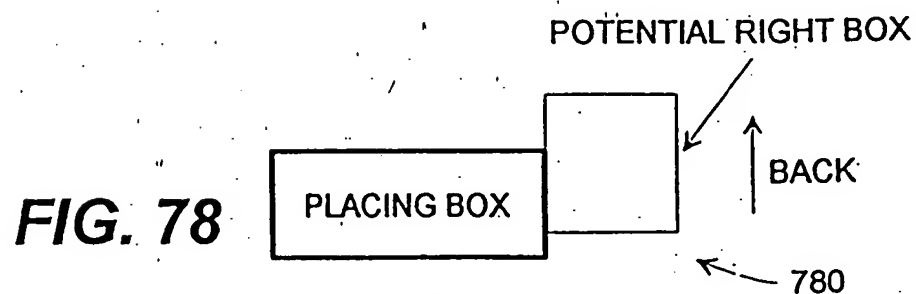
**FIG. 74**

**FIG. 75**

SIDE FRONT CORNER FIT

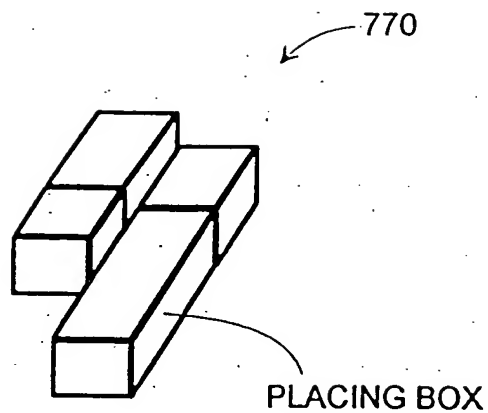
**FIG. 76****FIG. 77**

(A)

**FIG. 78**

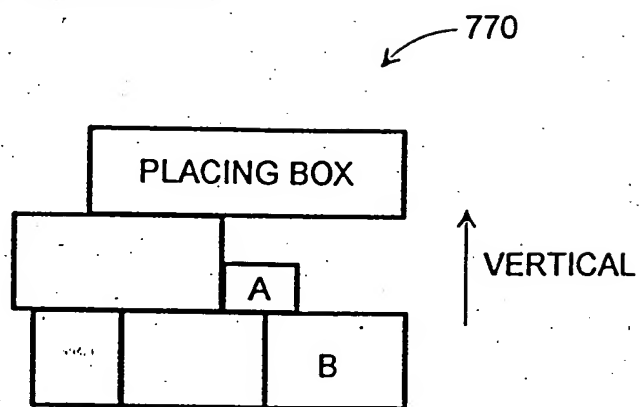
(B)

POTENTIAL RIGHT PLACEMENT



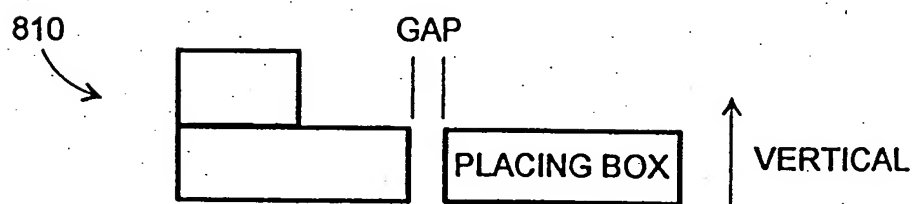
BOX OVEREXTENDS BEYOND SIDE NEIGHBORS

**FIG. 79**

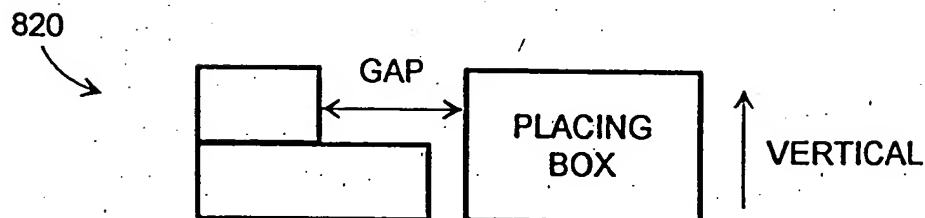


BLOCK LOW CORNERS

**FIG. 80**

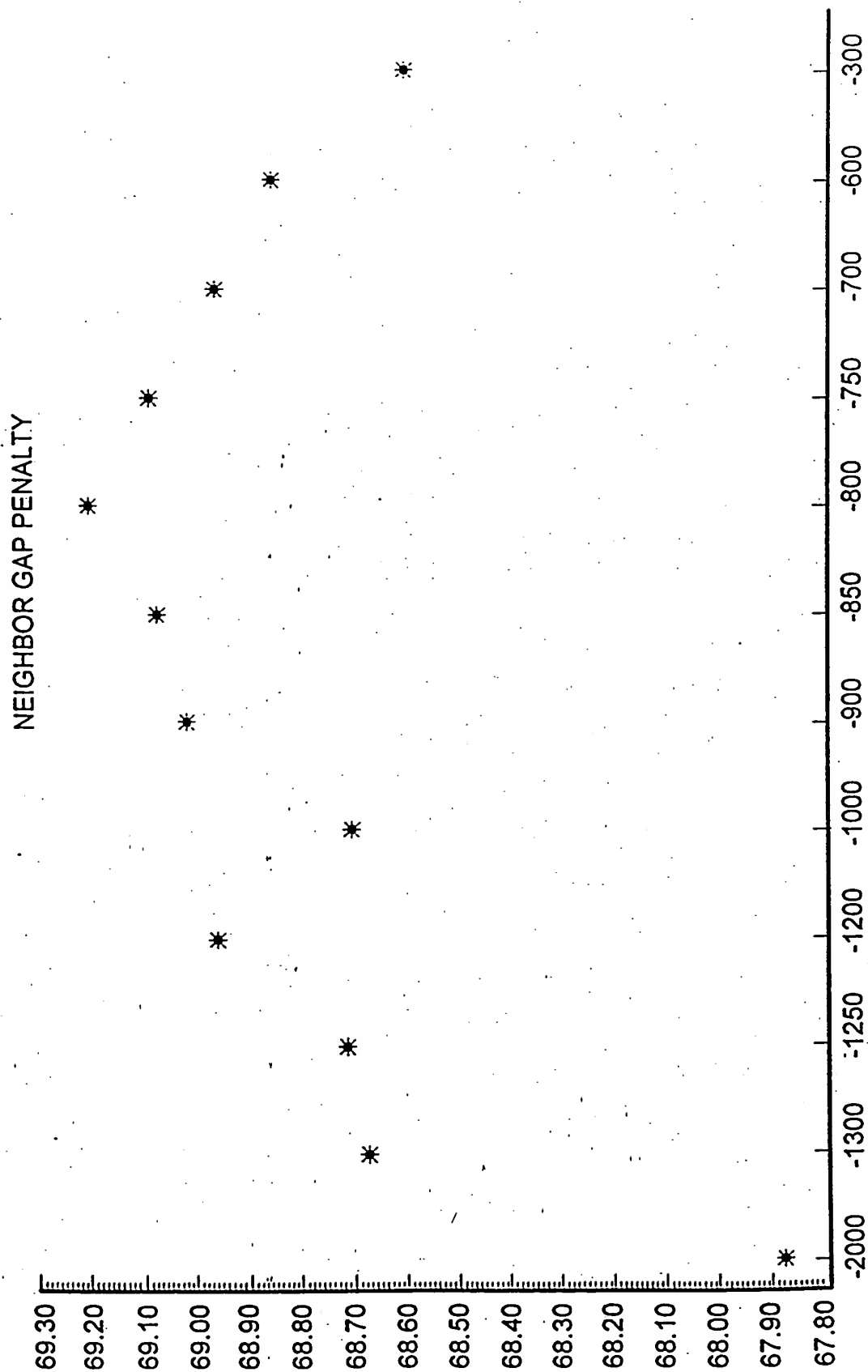


**FIG. 81**

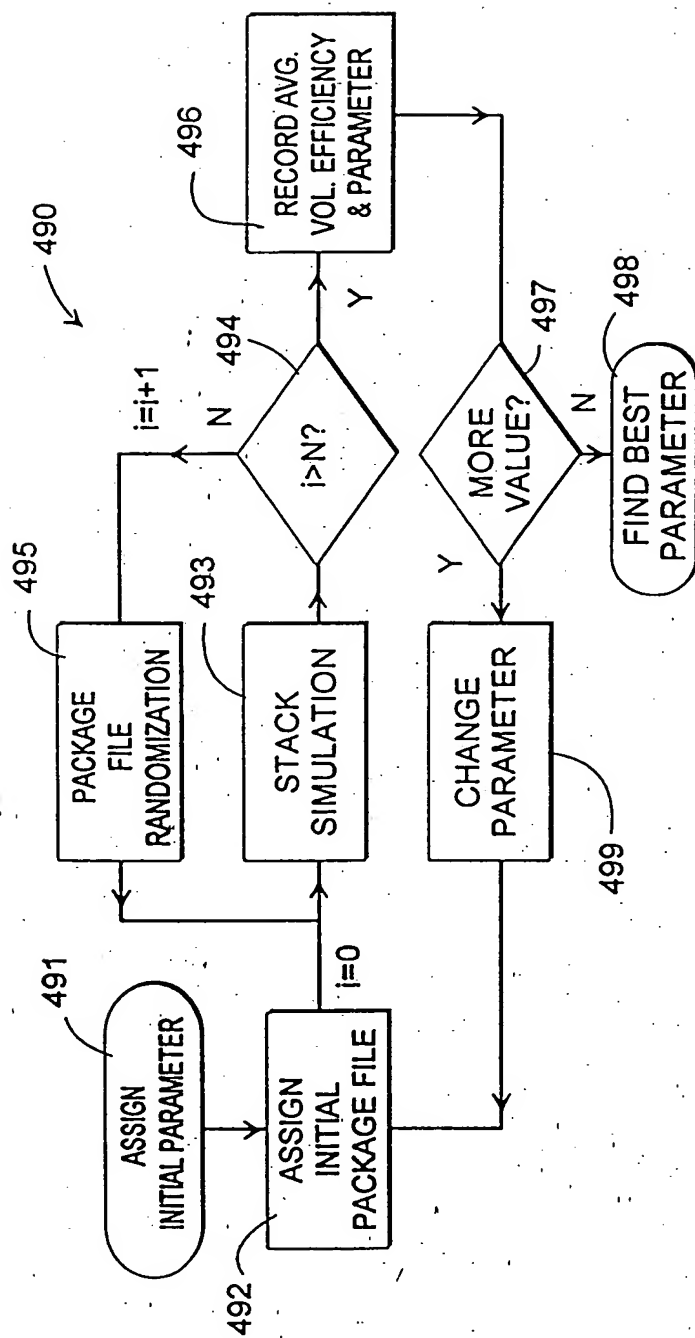


GAP TO NEIGHBOR BOX

**FIG. 82**

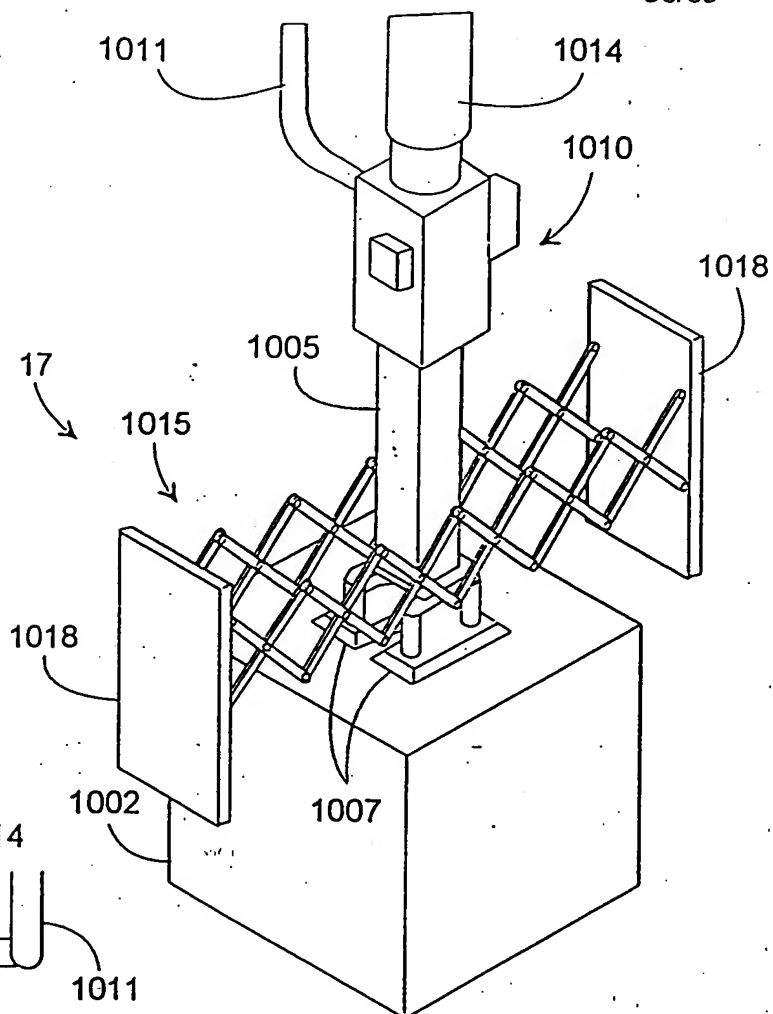
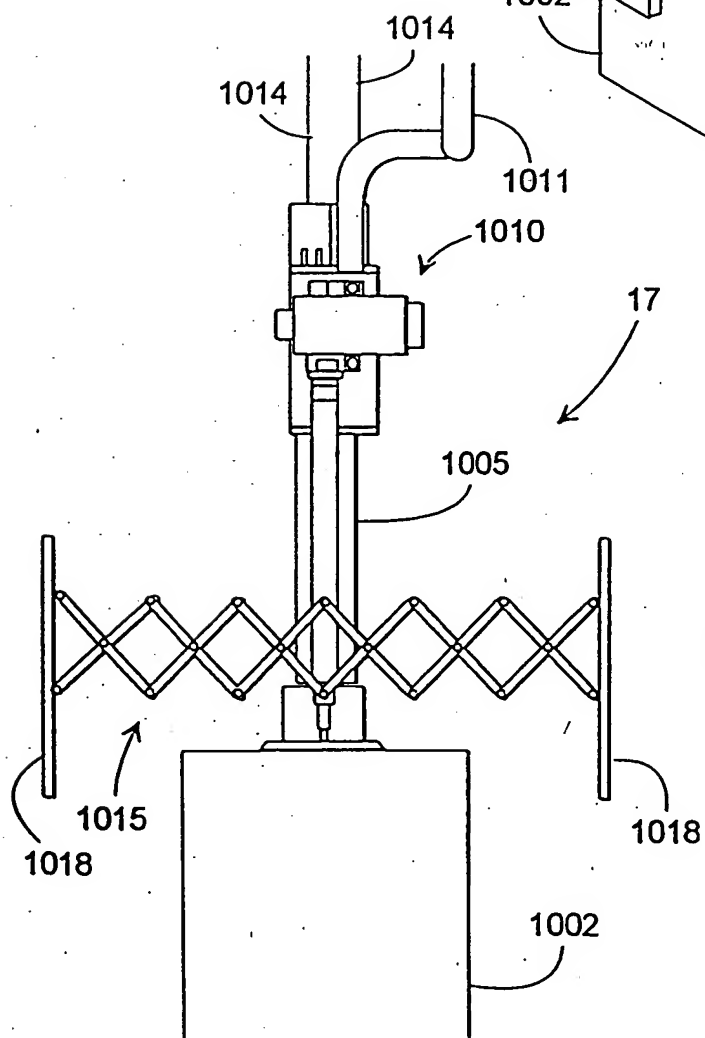
**FIG. 83**





AVERAGE VOLUME EFFICIENCY BASED PARAMETER SEARCH

**FIG. 84**

**FIG. 85****FIG. 86**

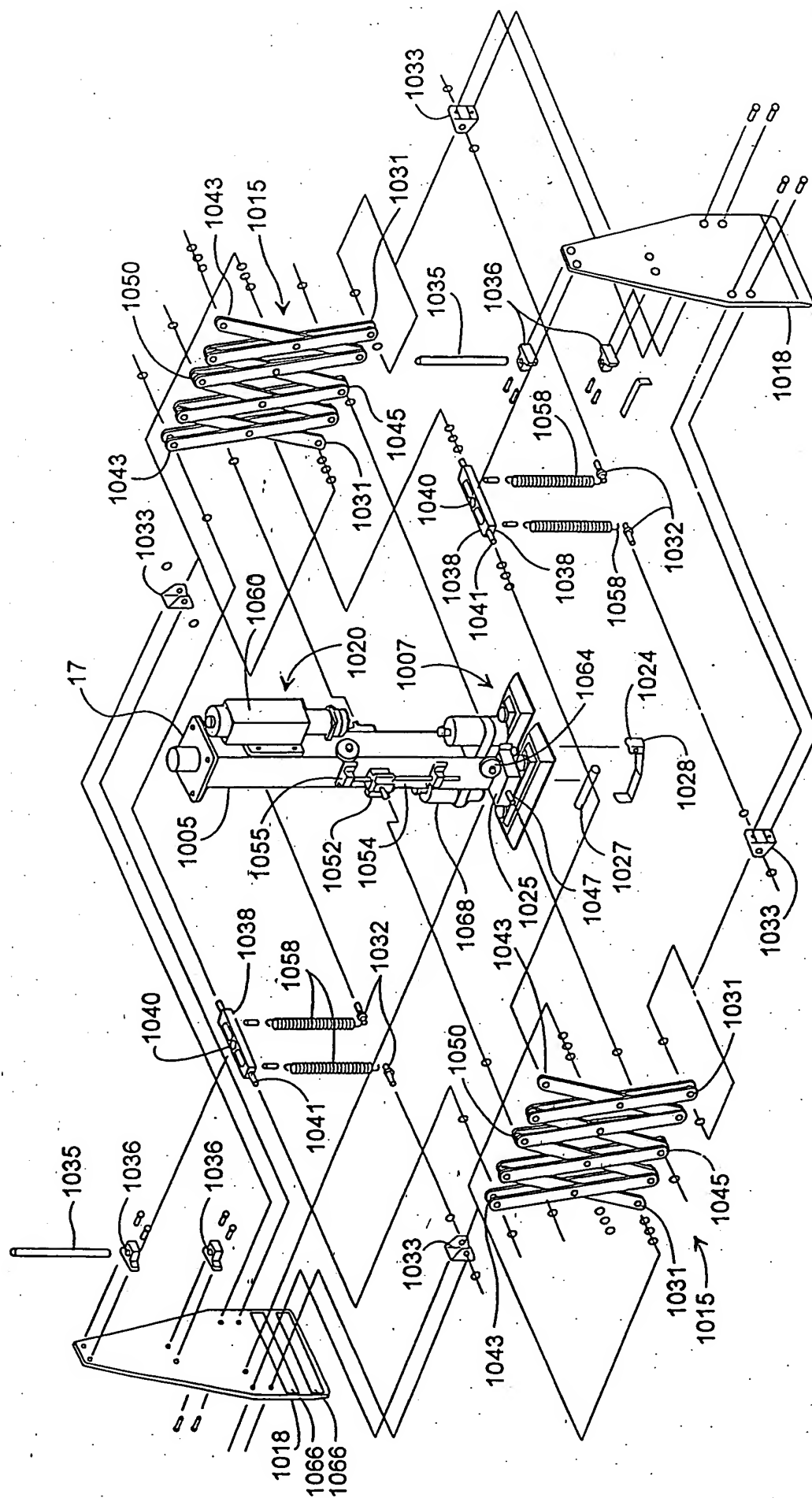
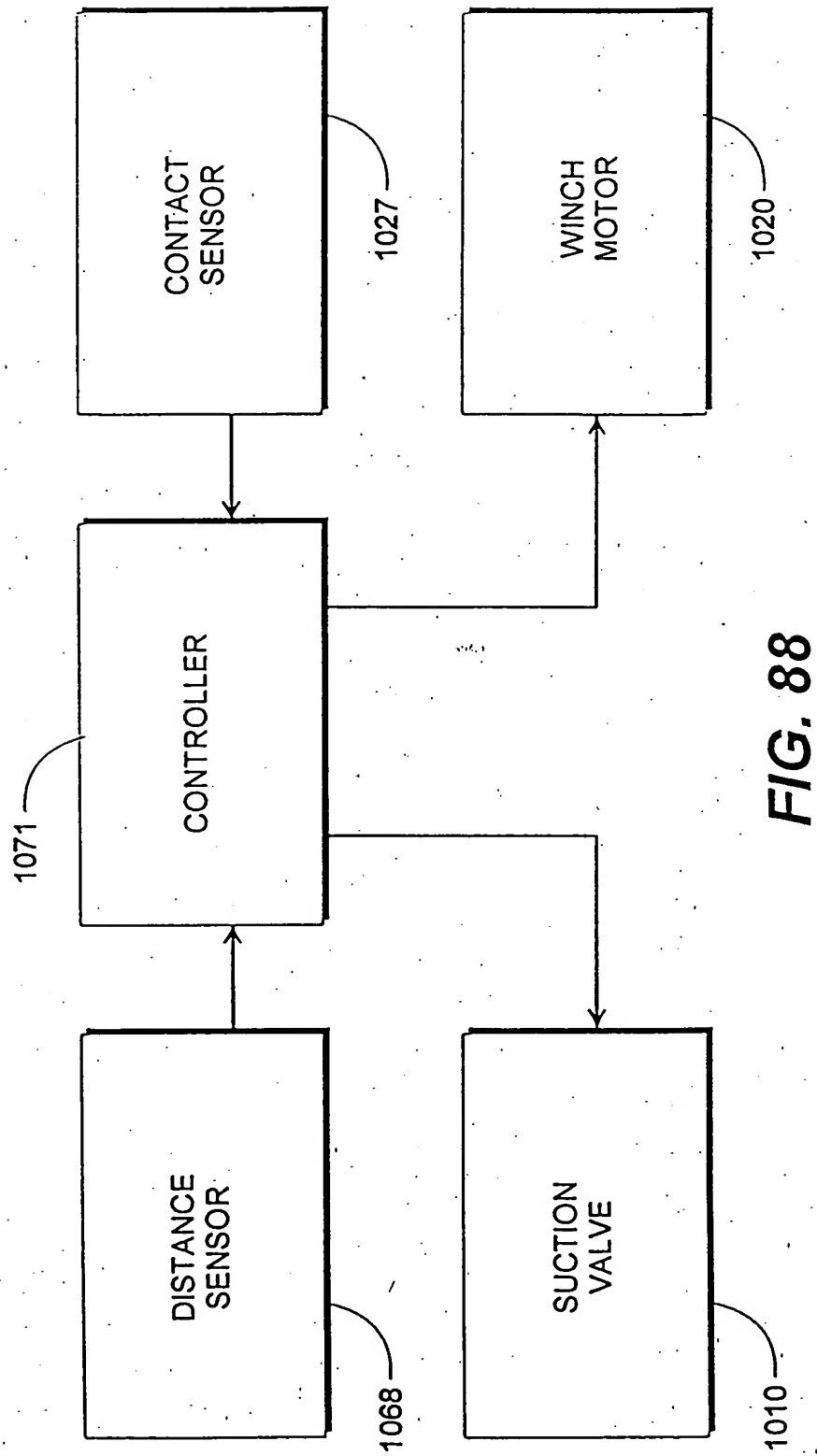


FIG. 87



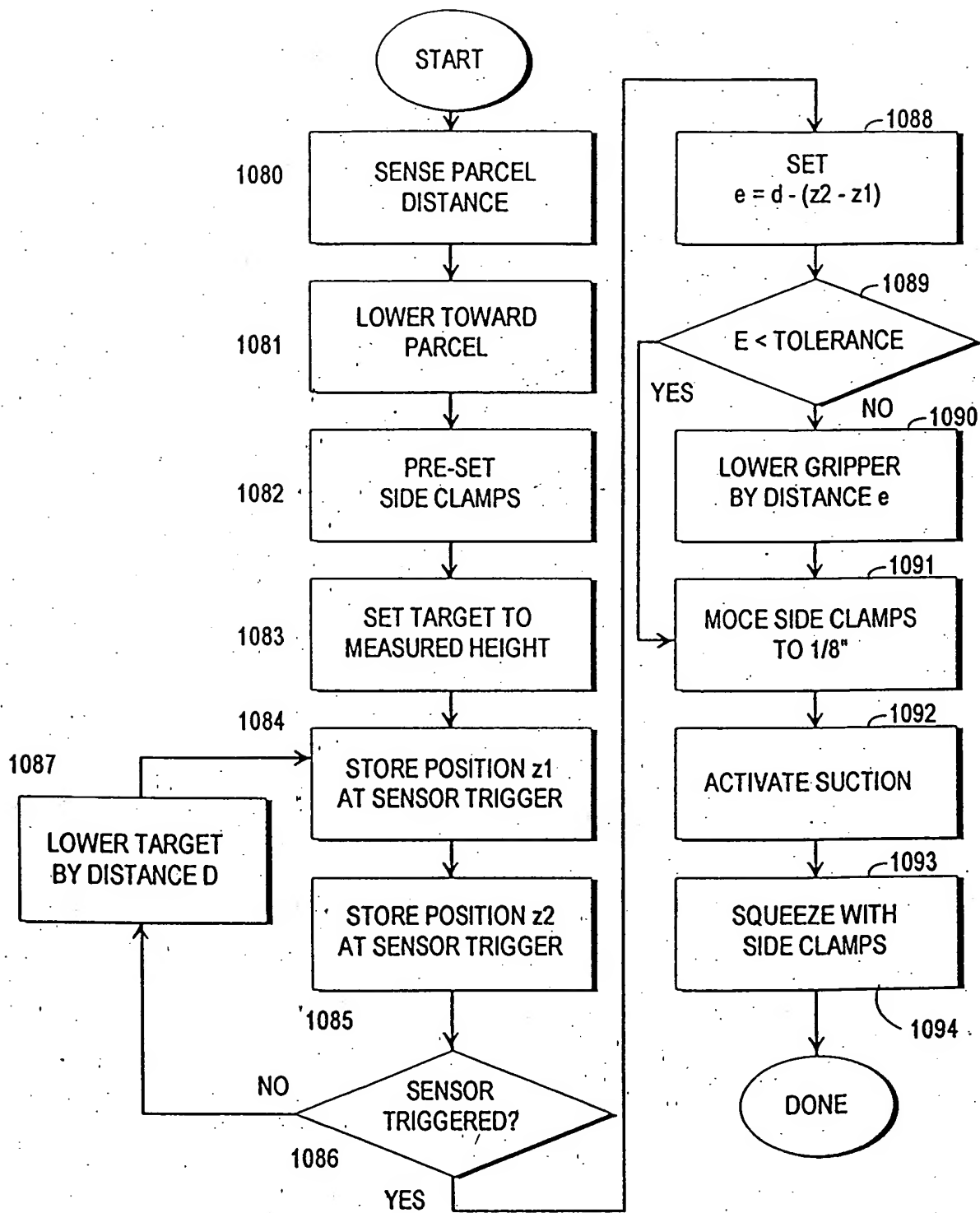
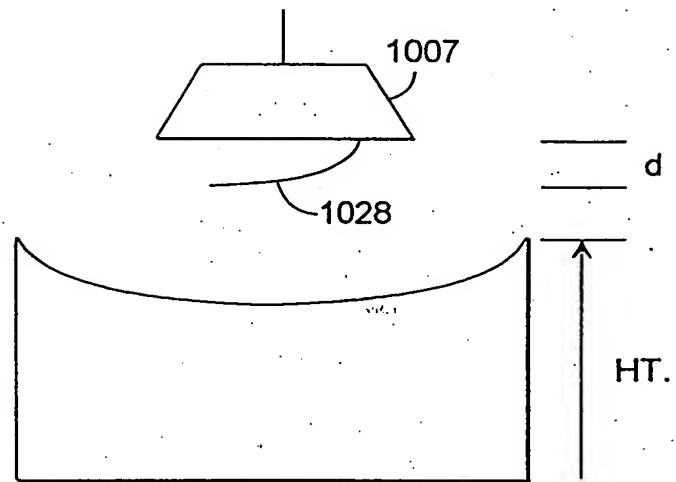
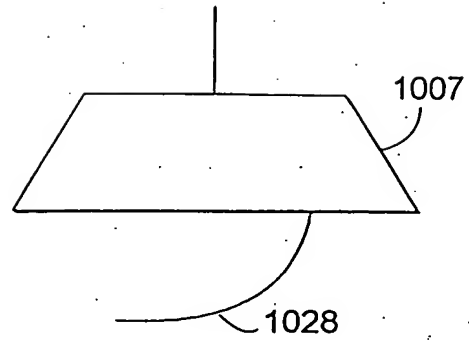
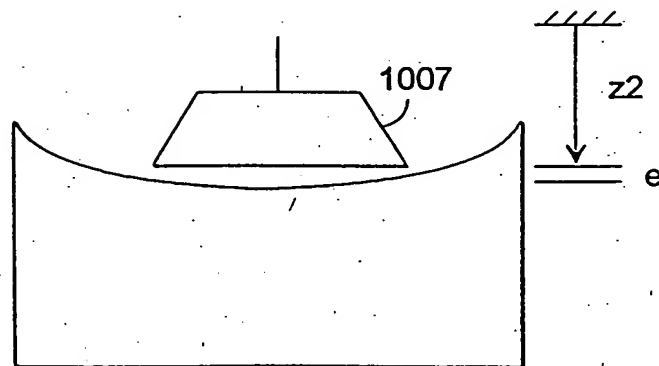
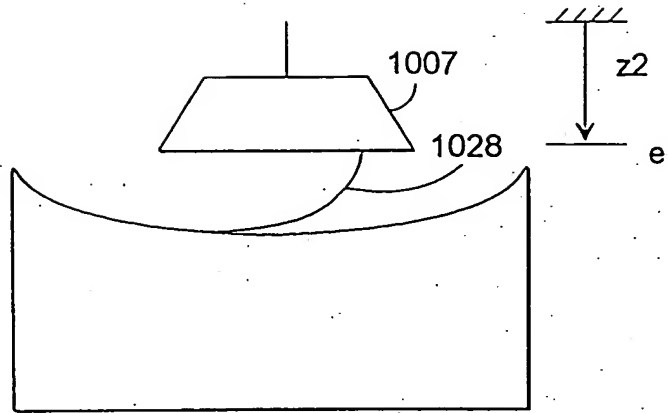
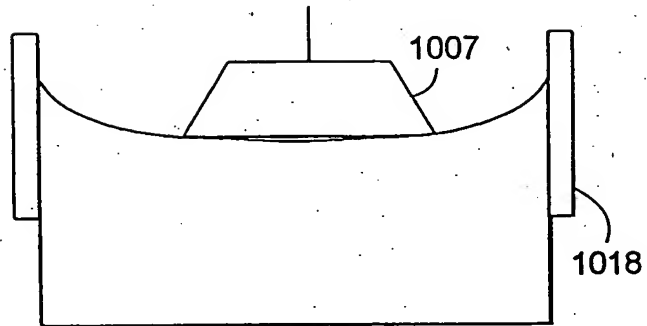
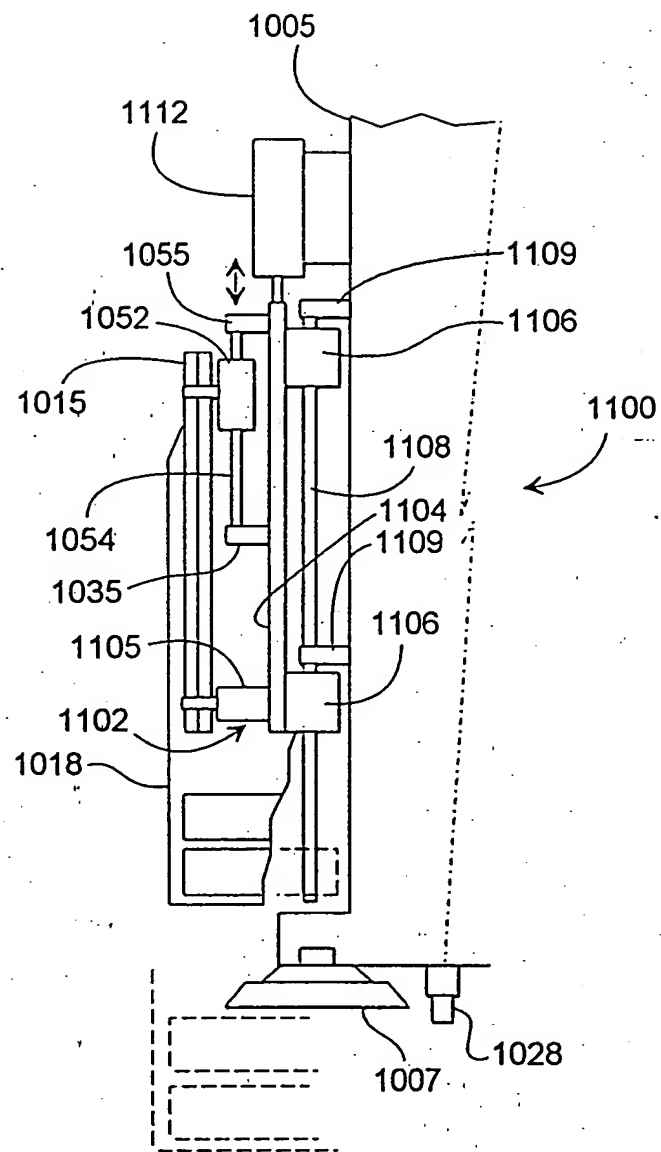


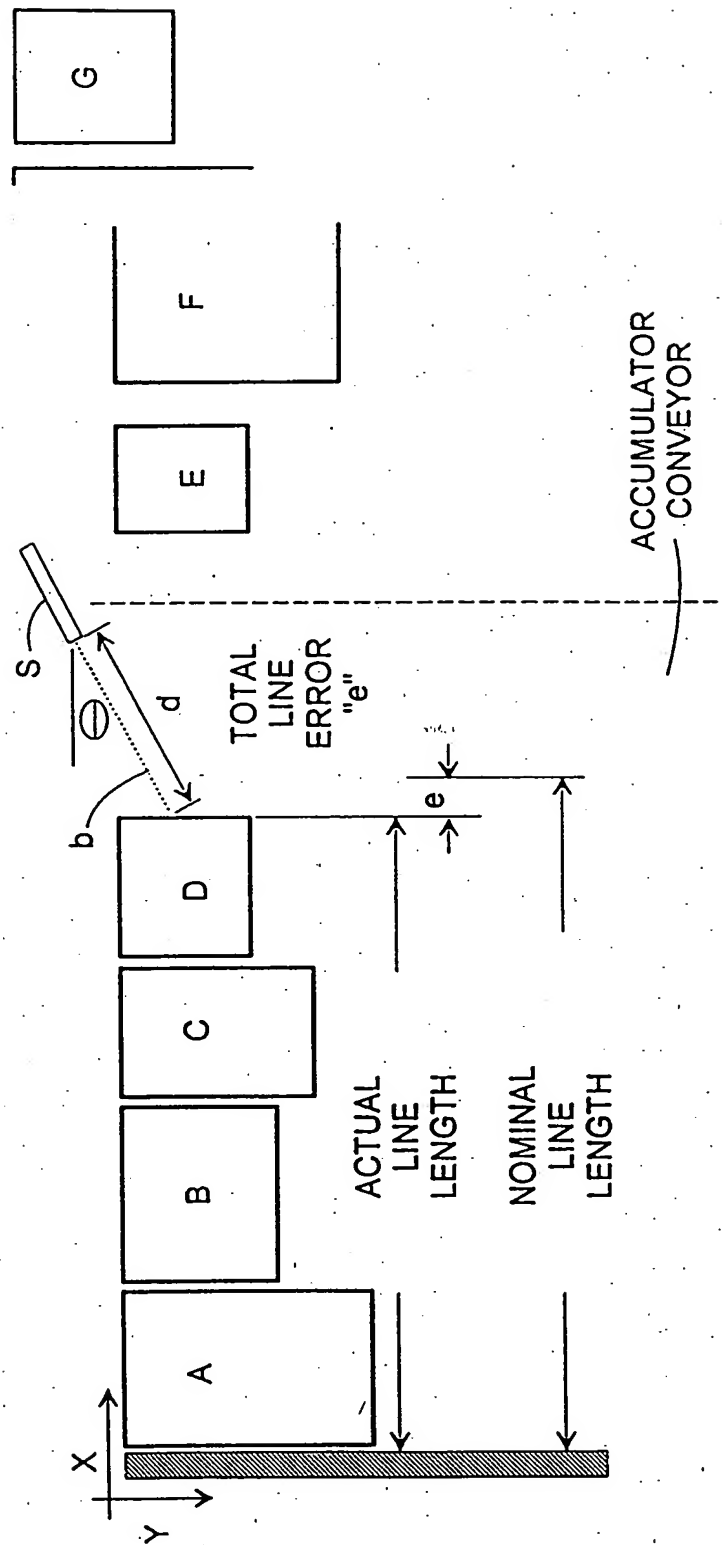
FIG. 89

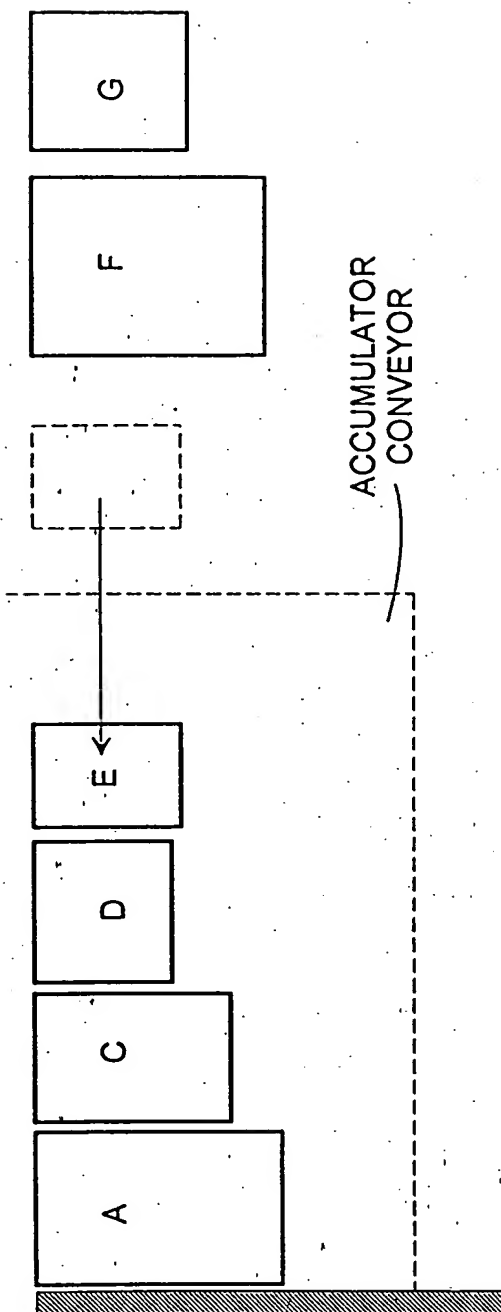
**FIG. 90****FIG. 91A****FIG. 91B**

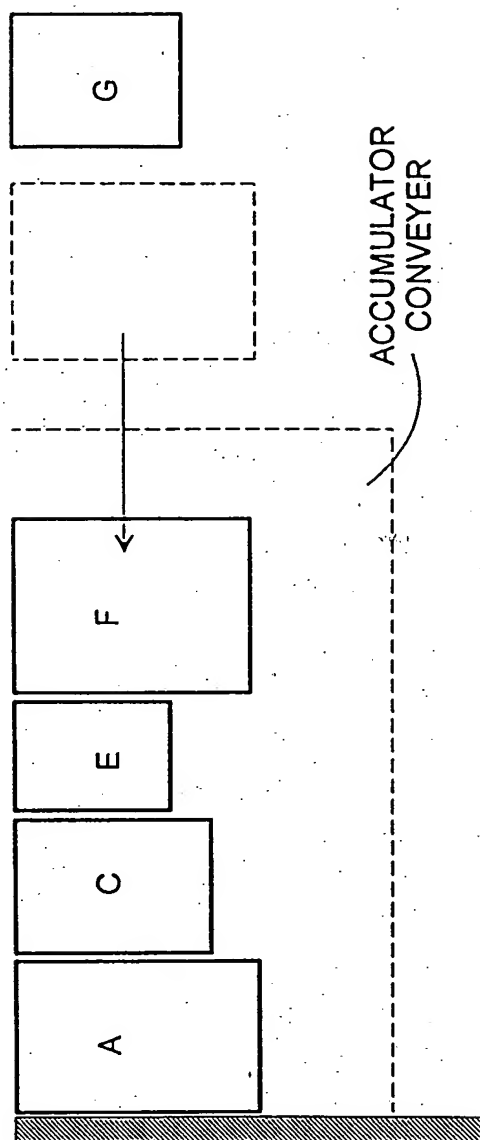
**FIG. 91C****FIG. 91D**

**FIG. 92**

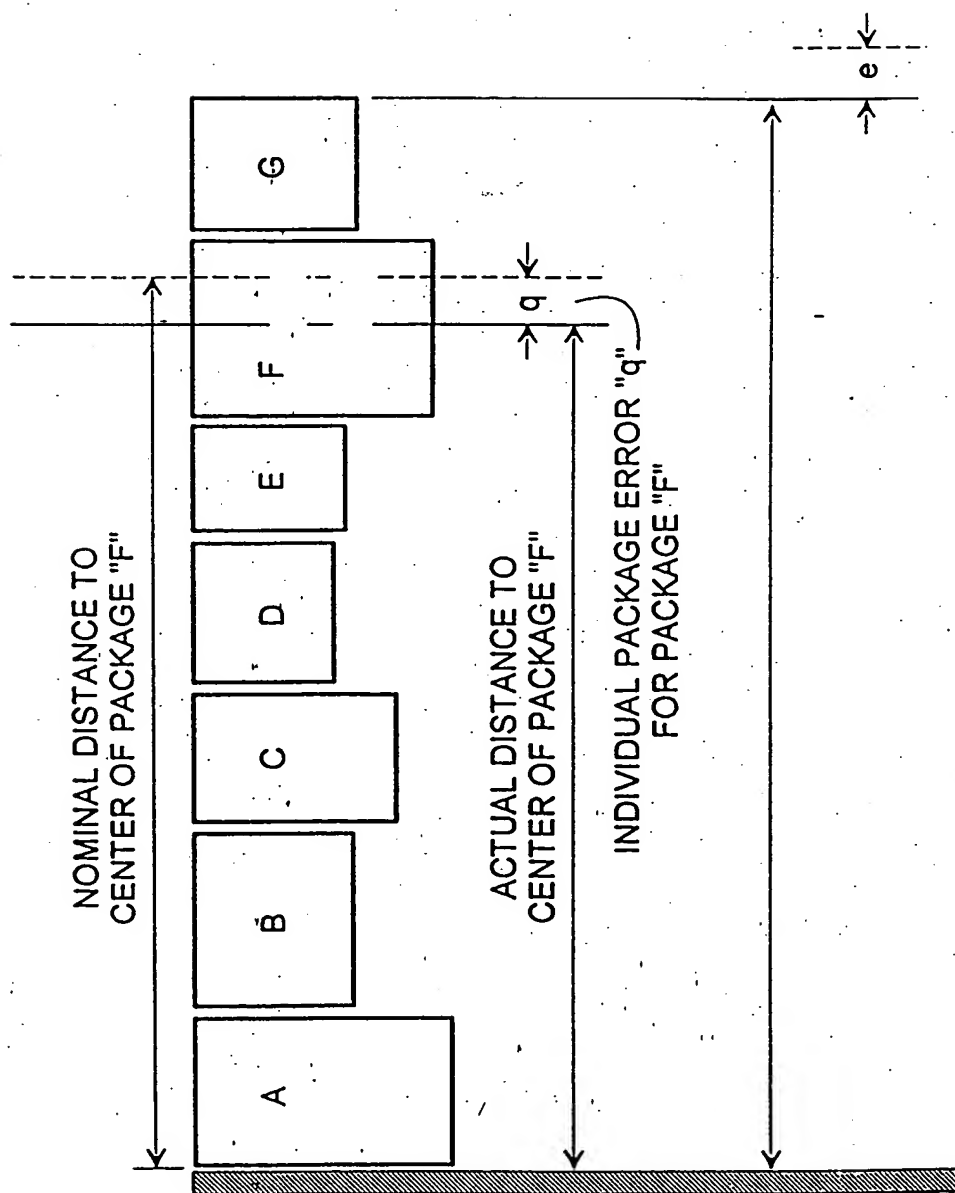


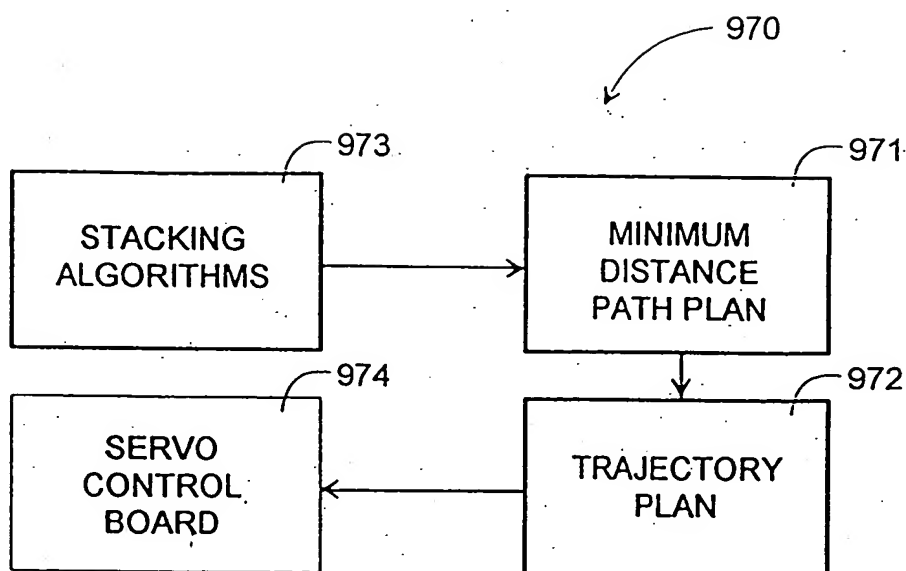
**FIG. 93**

**FIG. 94**

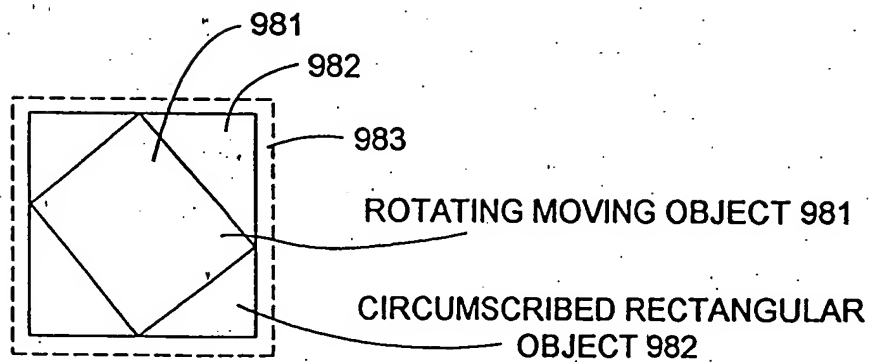


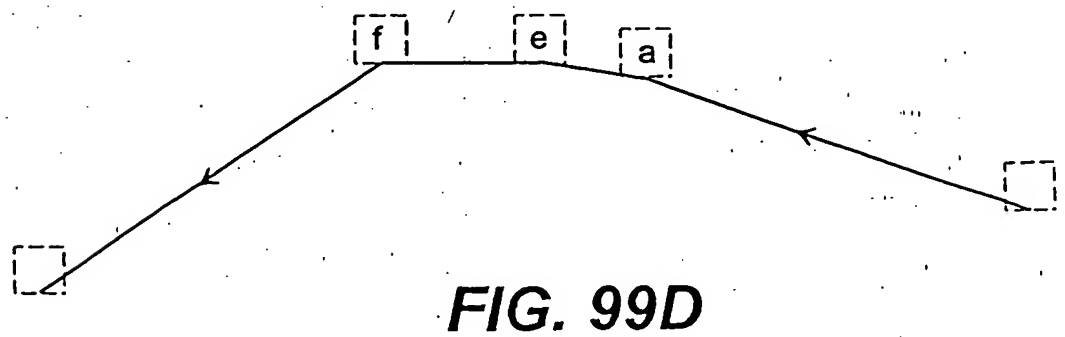
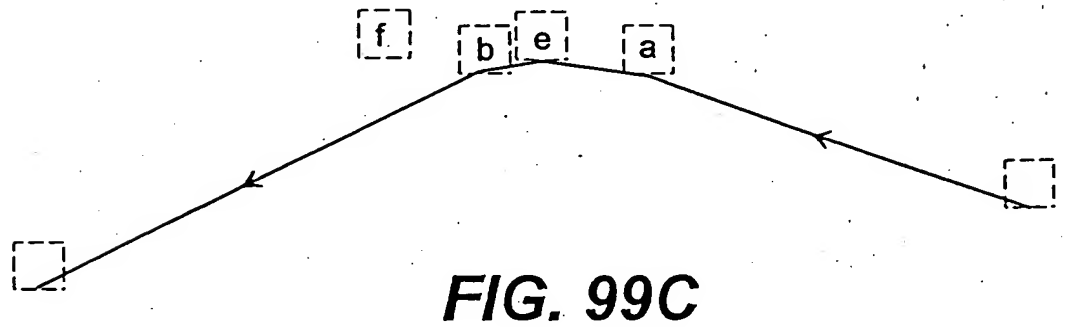
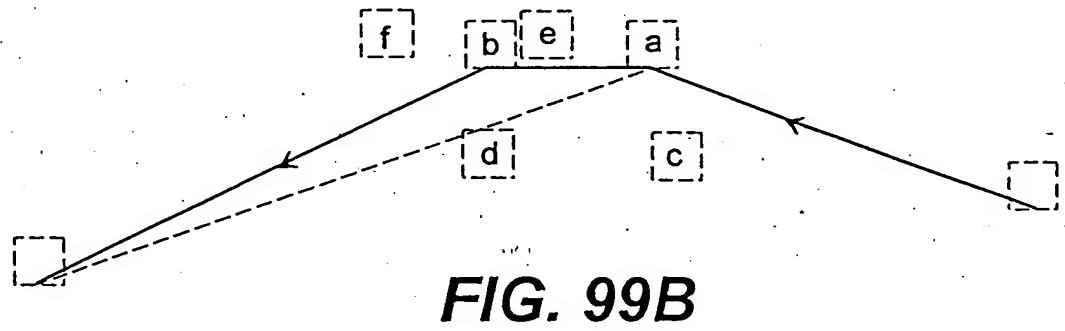
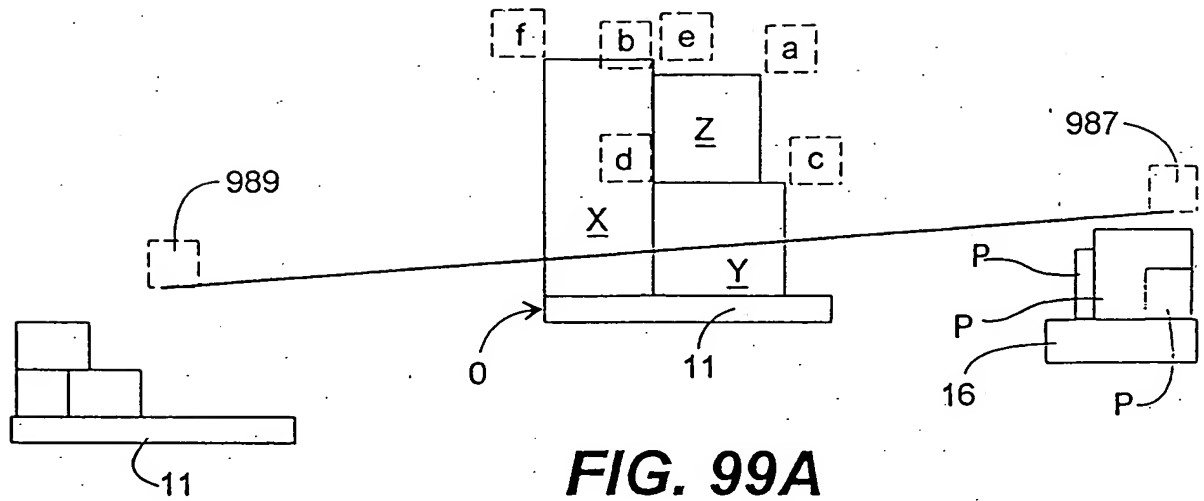
**FIG. 95**

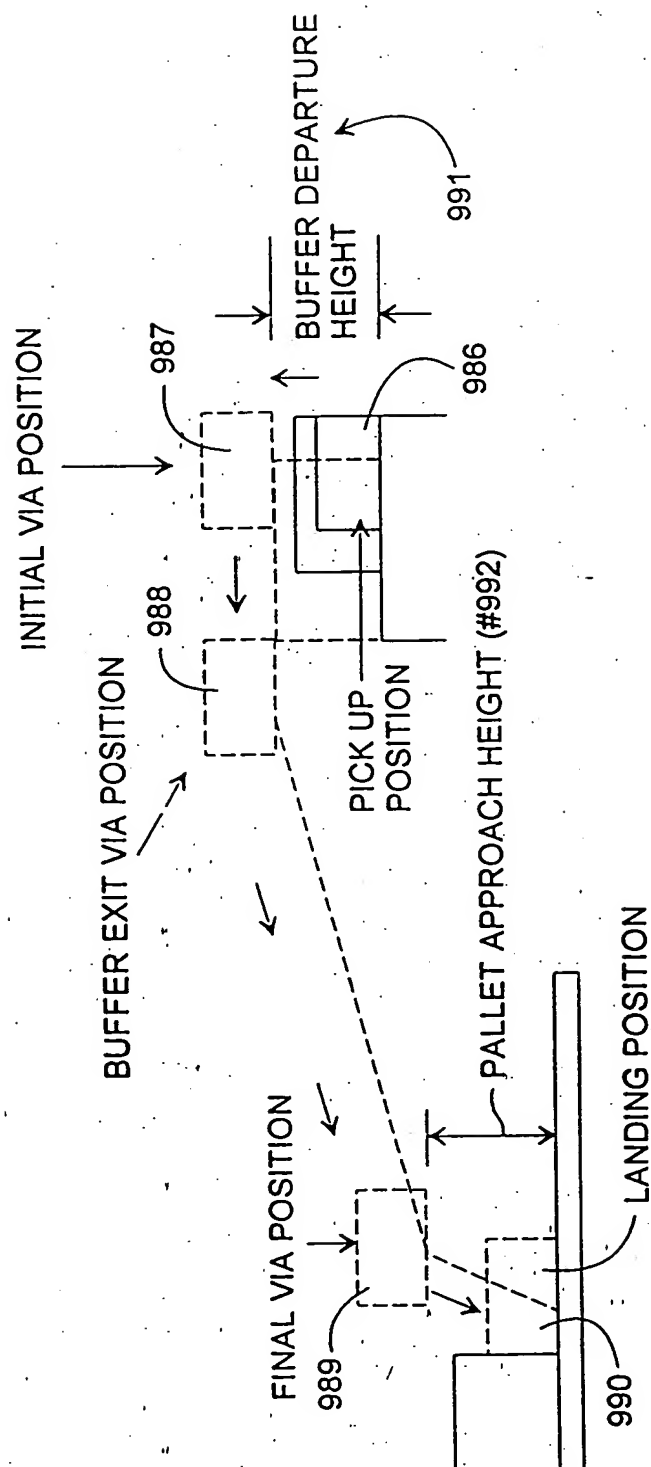
**FIG. 96**



SOFTWARE MODULES INTERACTION

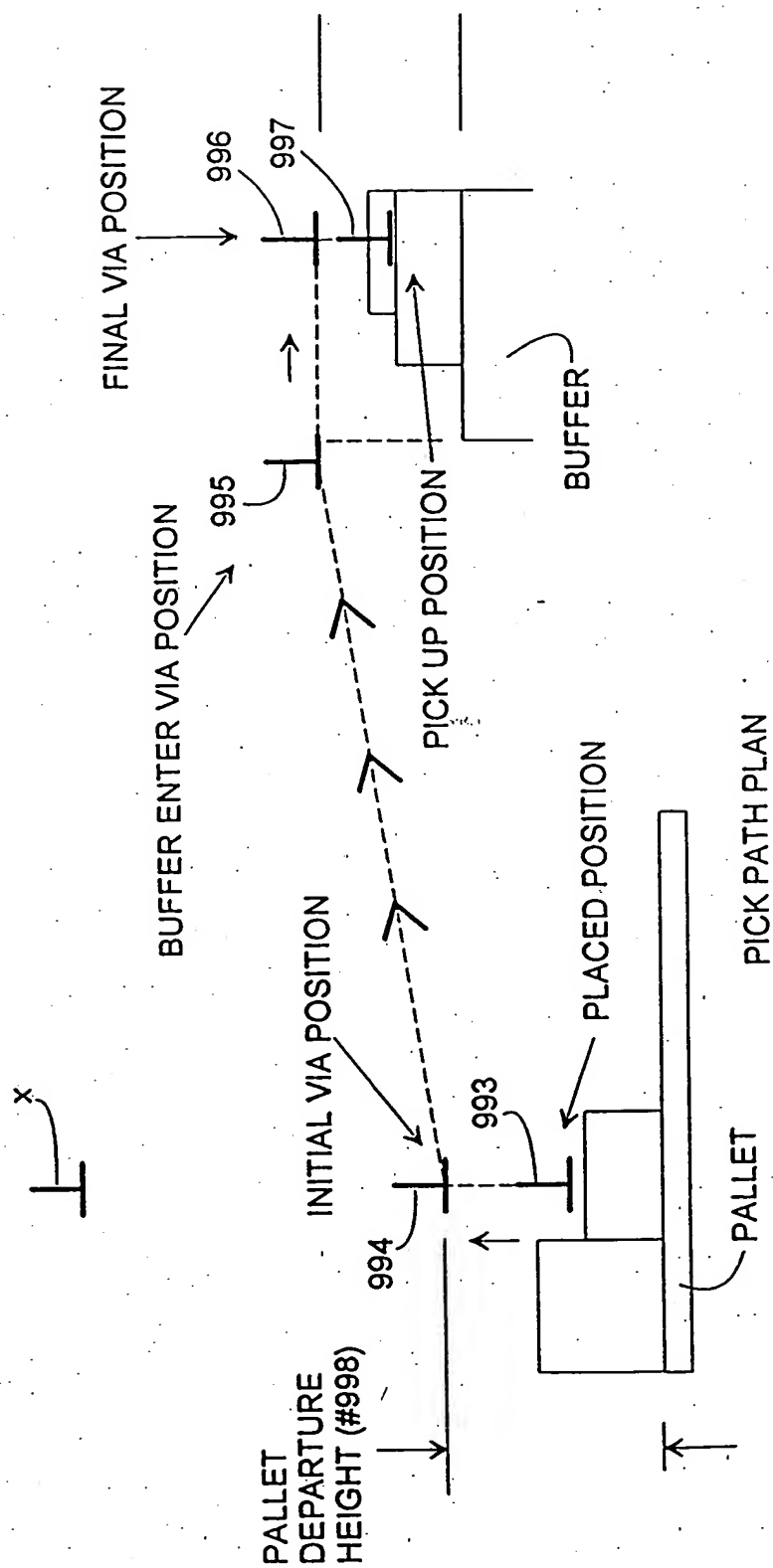
**FIG. 97****FIG. 98**



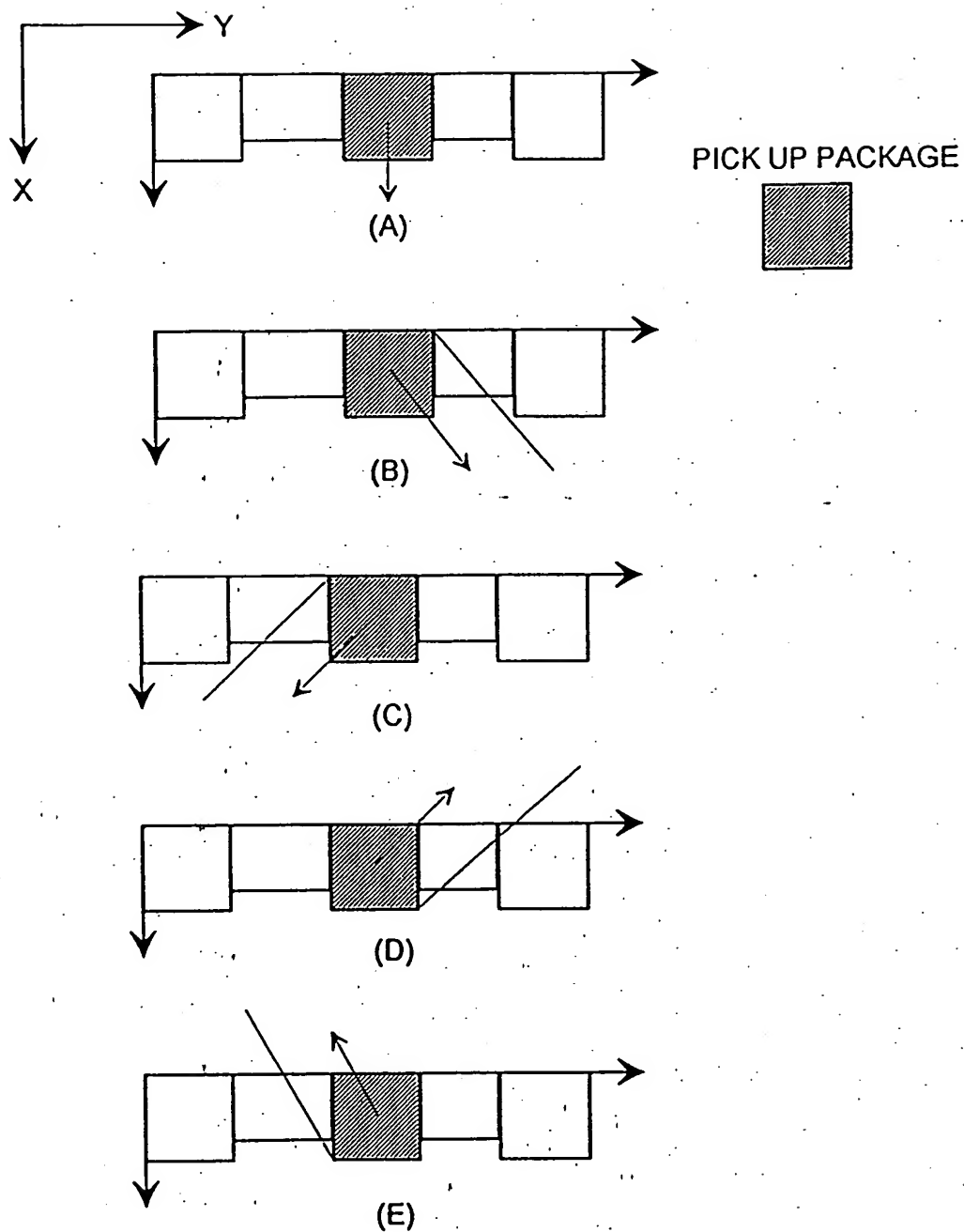


PLACEMENT PATH CONFIGURATION

**FIG. 100**

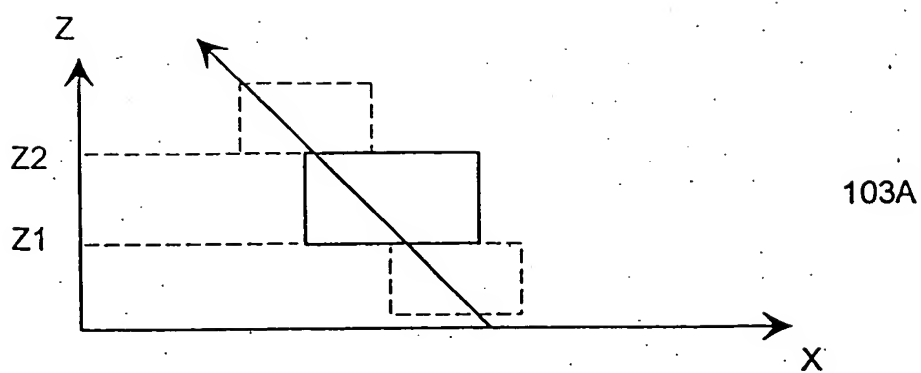
**FIG. 101**



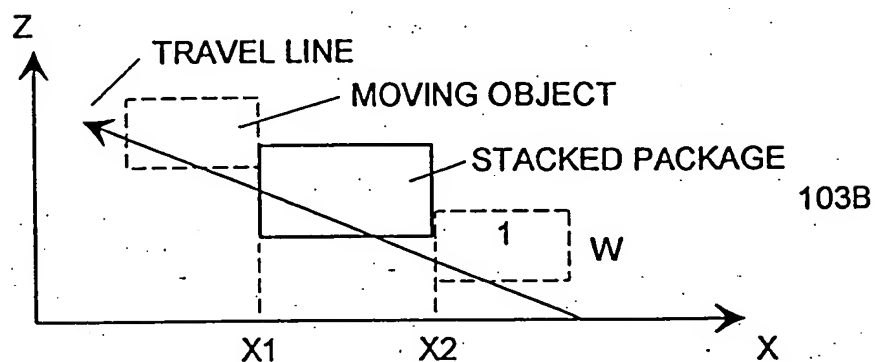


BUFFER LIFT HEIGHT COMPUTATION

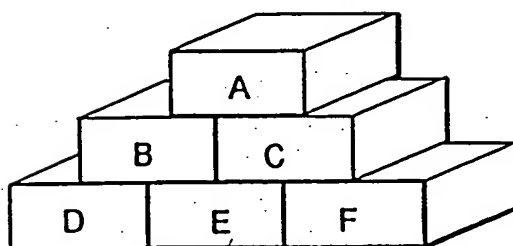
**FIG. 102**



(A)

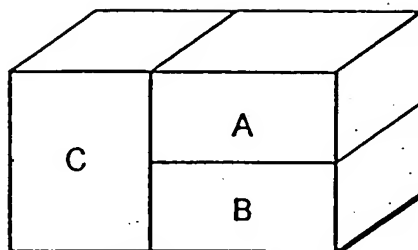


(B)

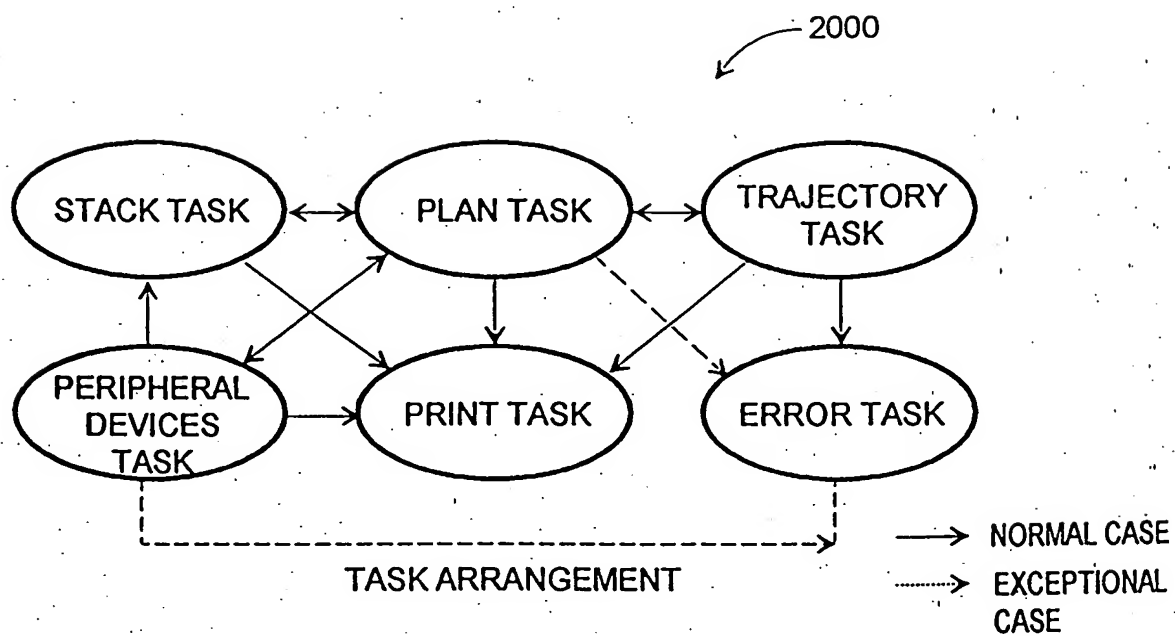
**FIG. 103**

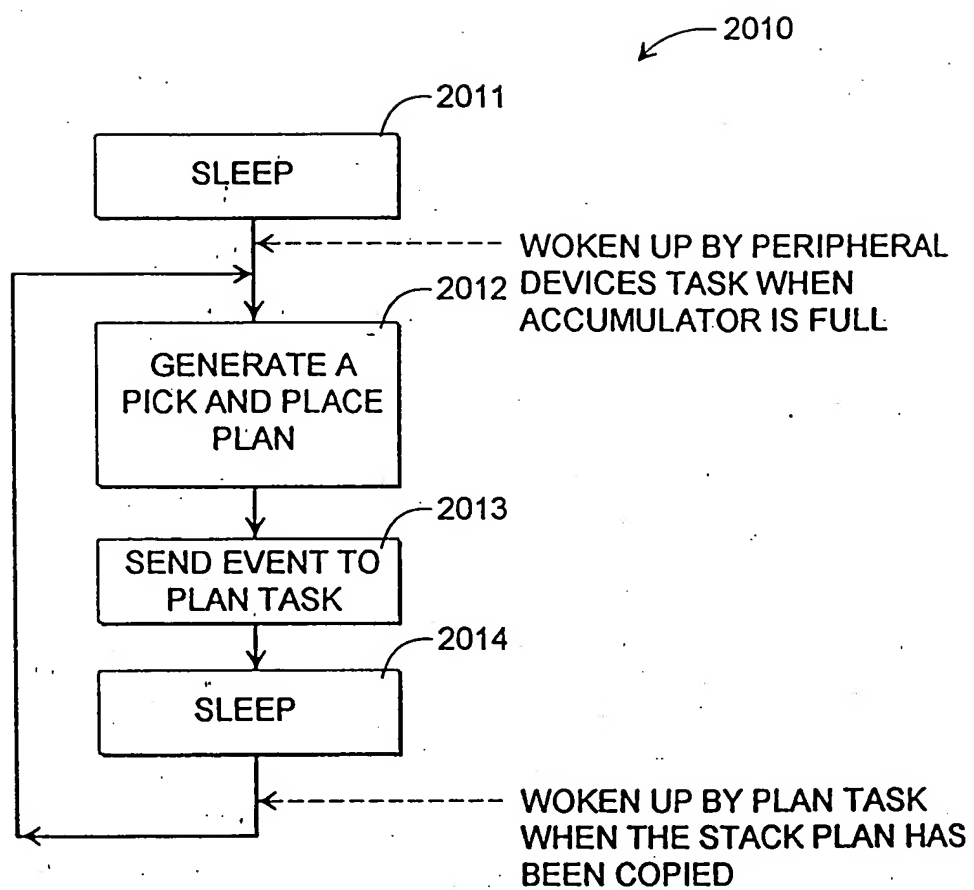
RE: WEIGHT PASSING FROM LAYER TO LAYER

**FIG. 104**



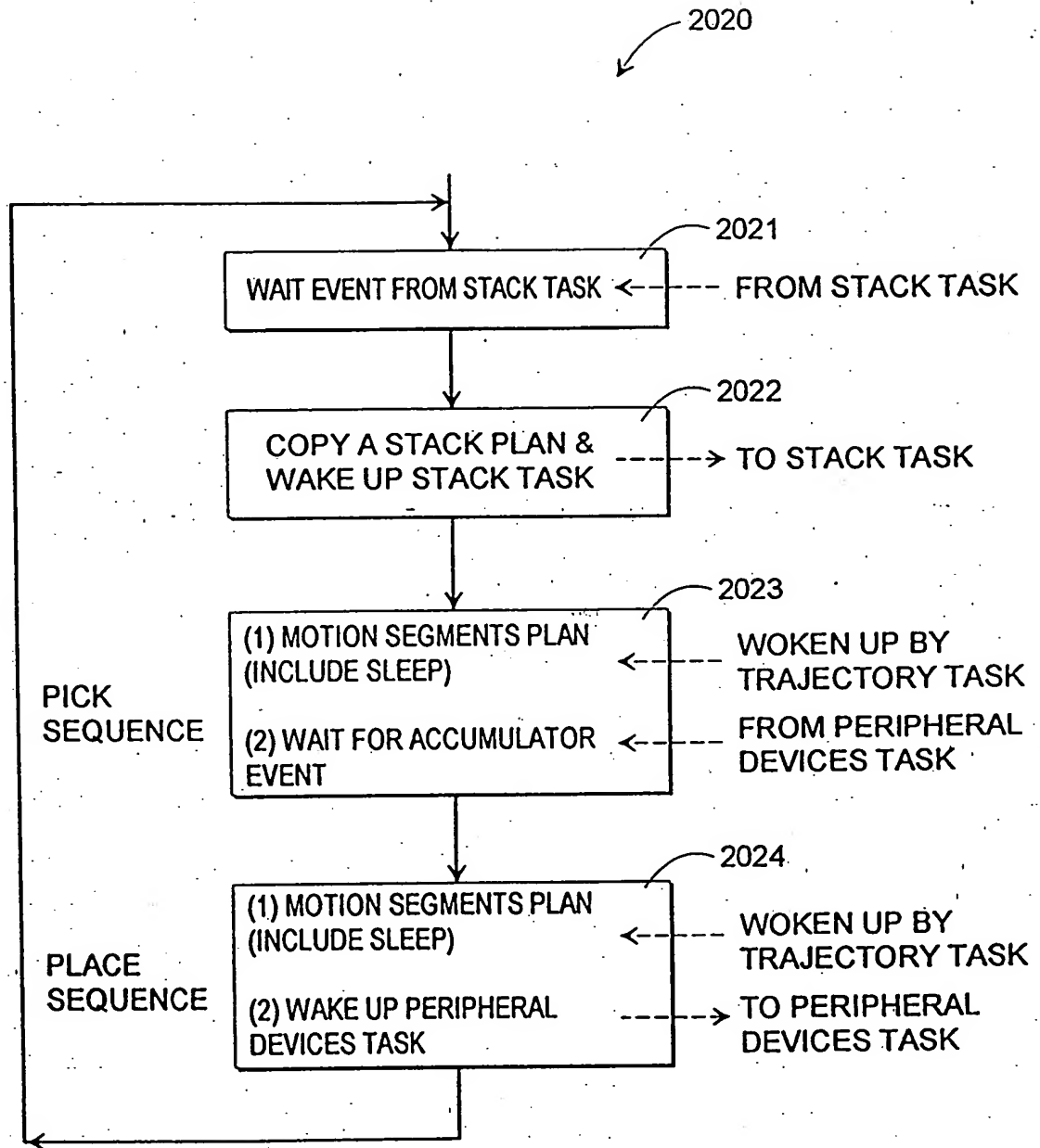
RE: WEIGHT PROPAGATION

**FIG. 105****FIG. 106**



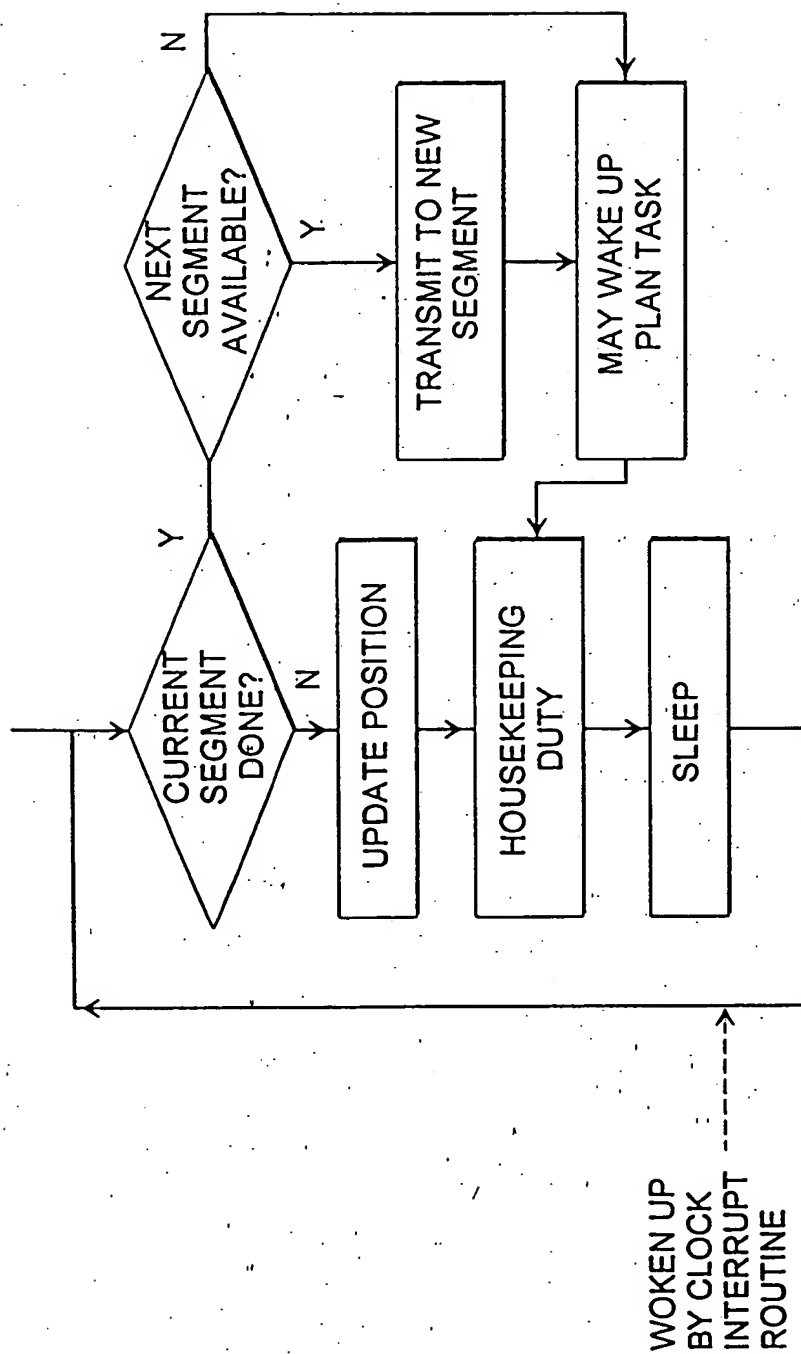
STACK TASK EXECUTION FLOW CHART

**FIG. 107**



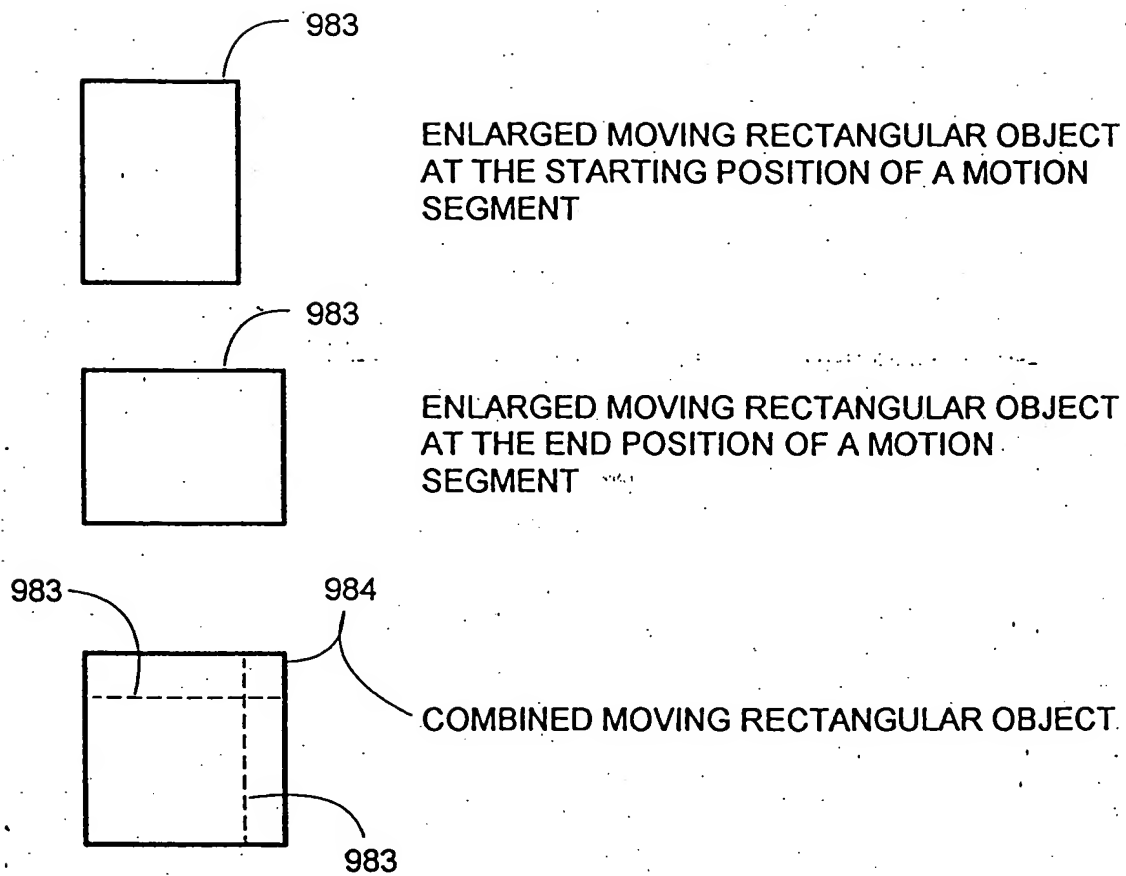
PLAN TASK EXECUTION FLOW CHART

**FIG. 108**



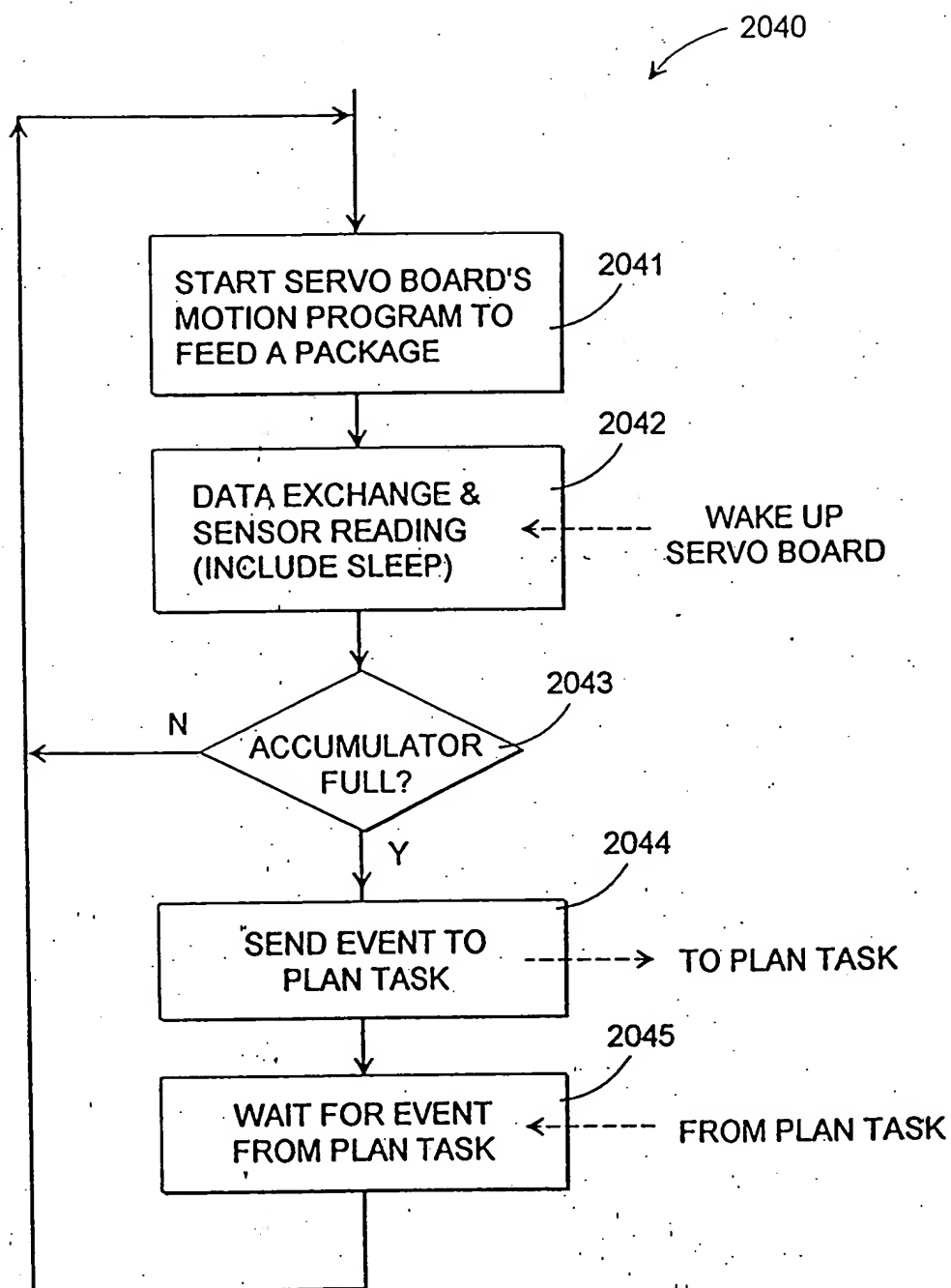
TRAJECTORY TASK EXECUTION FLOW CHART

**FIG. 109**



COMBINED MOVING RECTANGULAR OBJECT DEFINITION

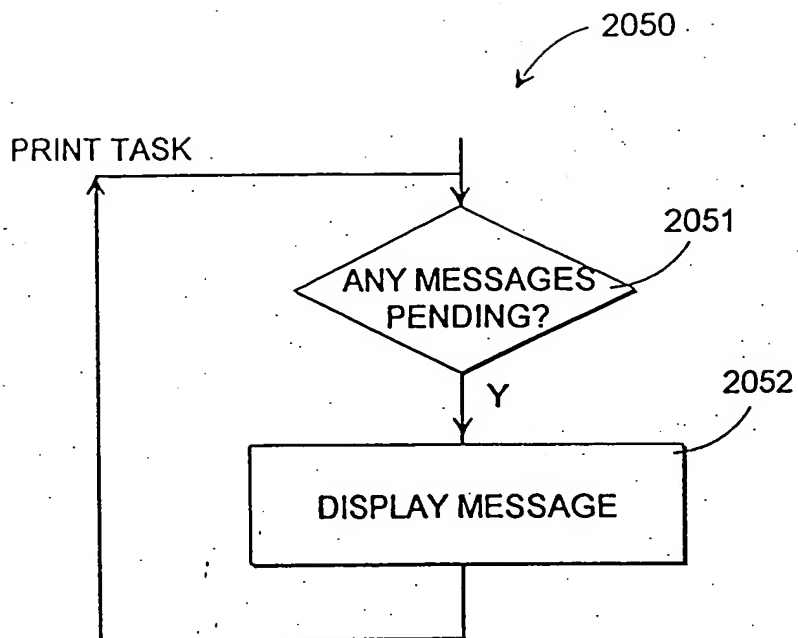
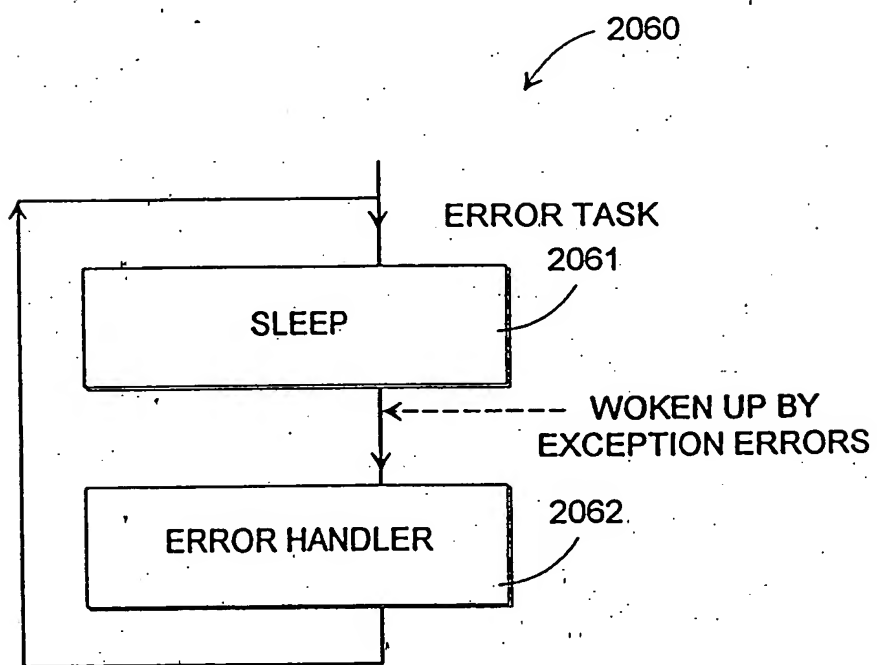
**FIG. 110**

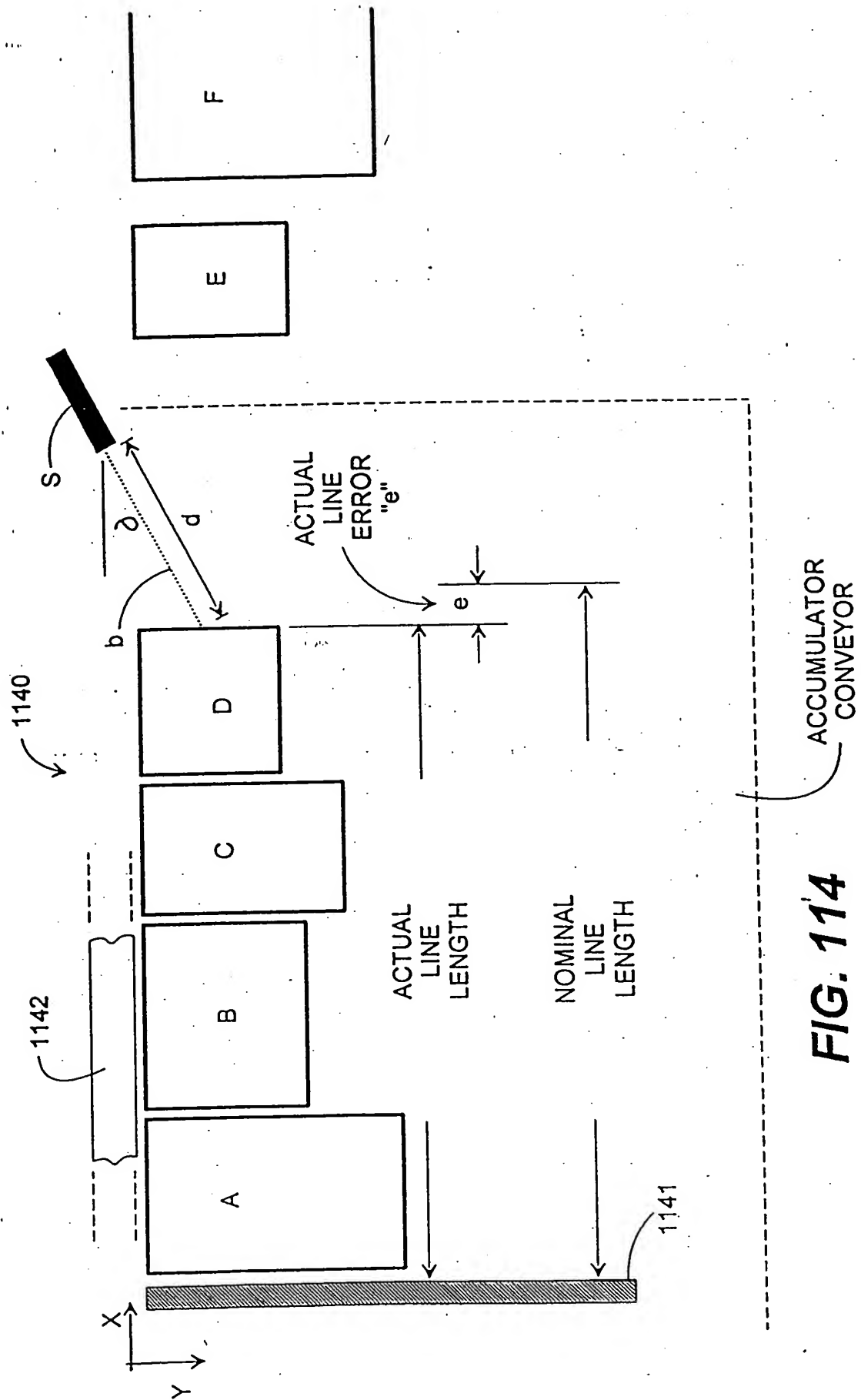


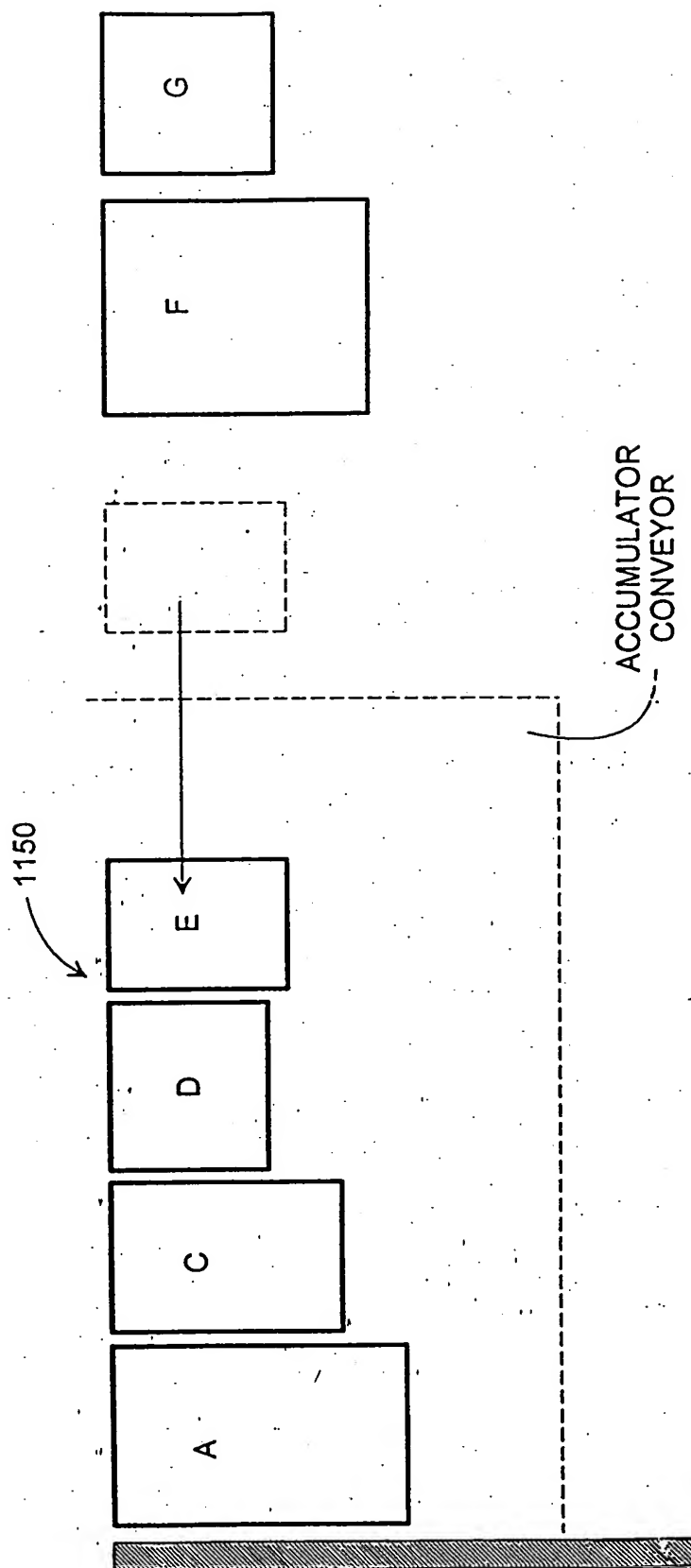
PERIPHERAL DEVICES TASK EXECUTION FLOW CHART

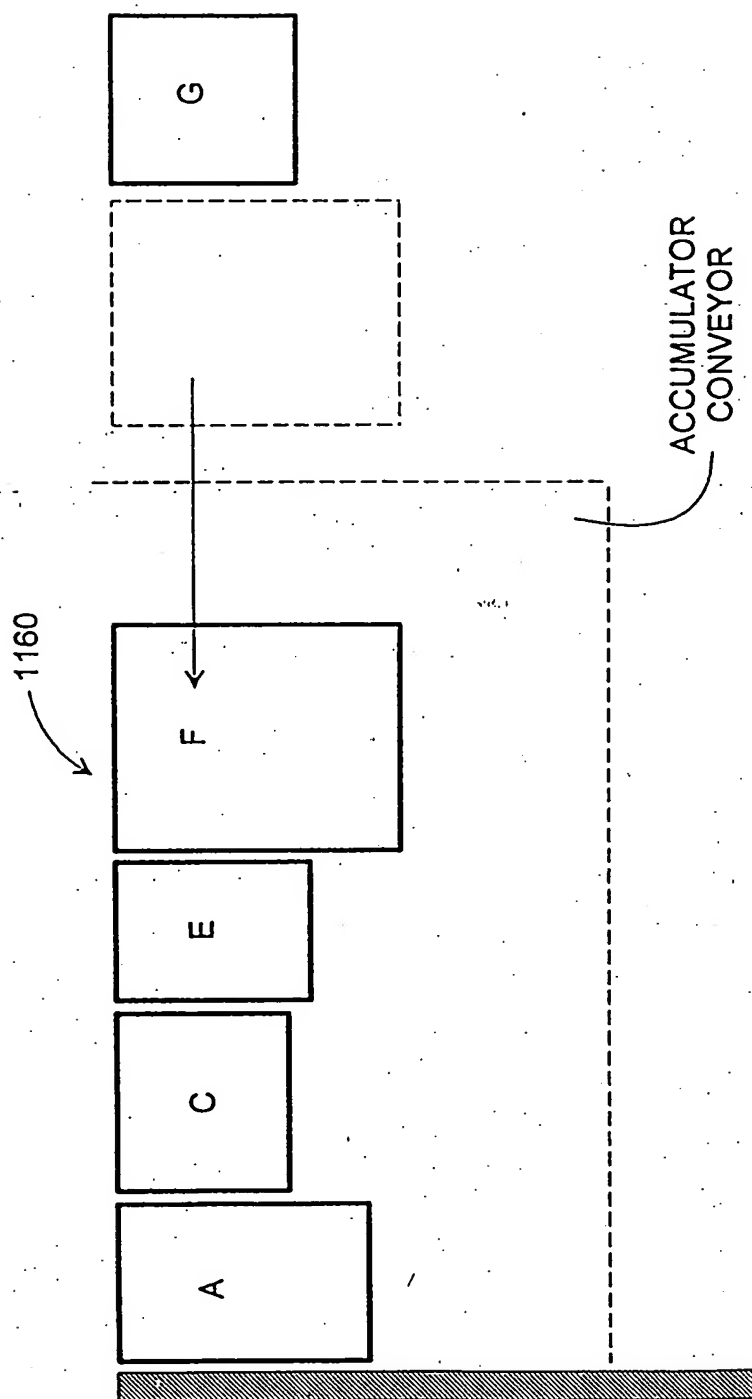
**FIG. 111**

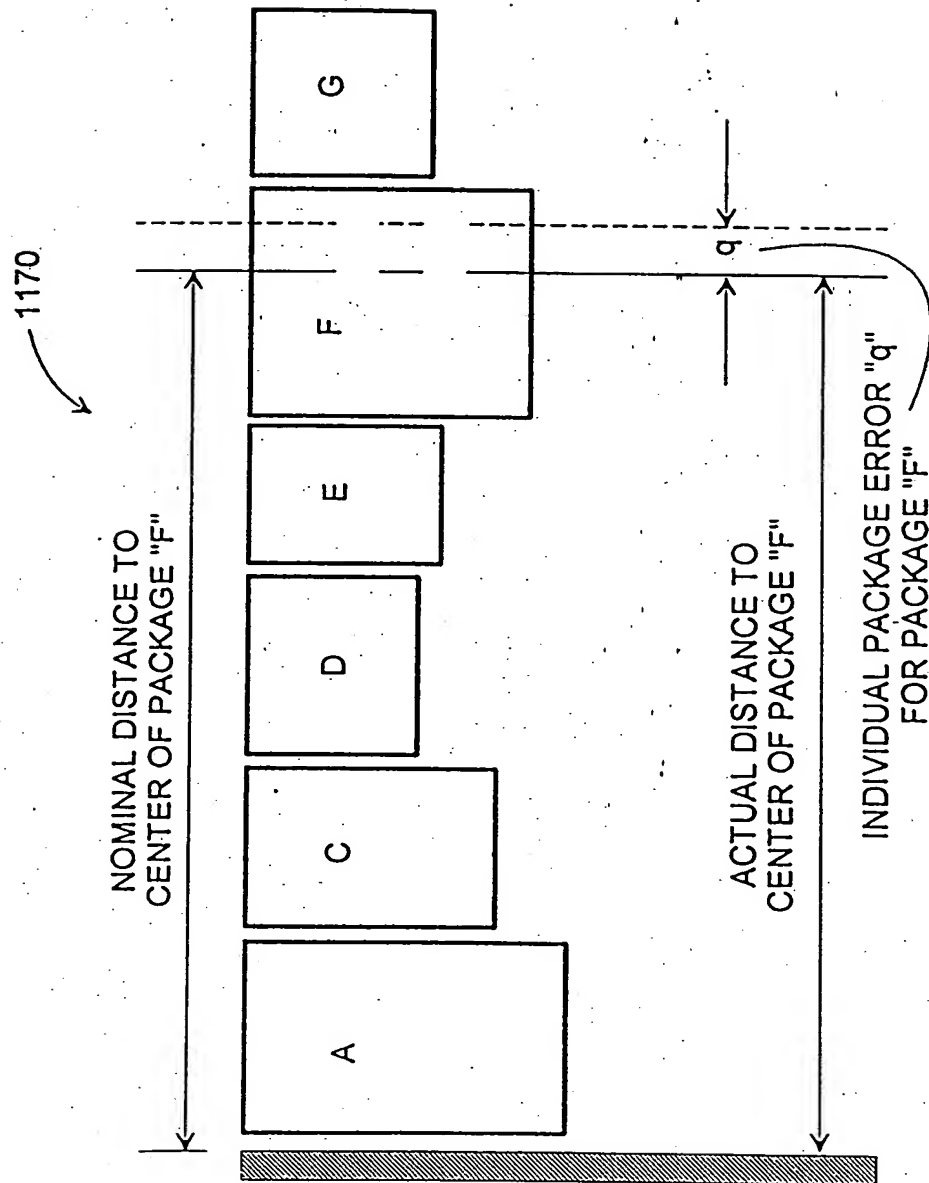


**FIG. 112****FIG. 113**



**FIG. 115**

**FIG. 116**

**FIG. 117**